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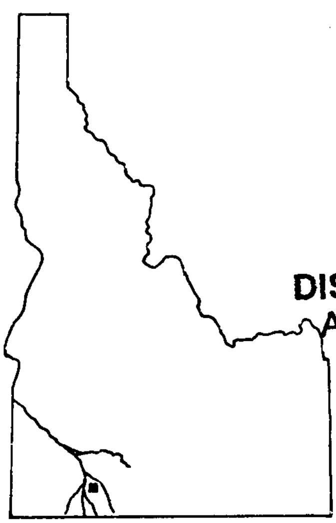
PNE - 509

Plowshare civil, industrial and scientific uses for nuclear explosives

UNITED STATES ARMY CORPS OF ENGINEERS

BRUNEAU PLATEAU, IDAHO
30 September 1965



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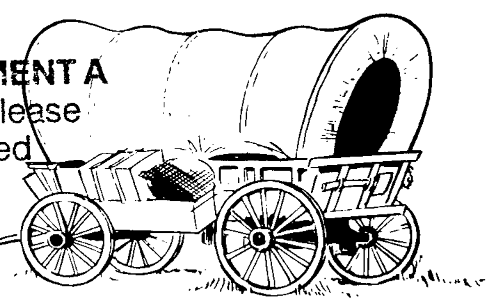
P R O J E C T
PRE-SCHOONER II



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PRESHOT GEOLOGIC AND ENGINEERING PROPERTIES INVESTIGATIONS

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Livermore, California

ISSUED: December 1967

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PROJECT PRE-SCHOONER II

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ABSTRACT

The Pre-Schooner II site was selected, from five areas investigated, on the basis of refraction seismic surveying, core drilling, and surface mapping in extrusive igneous rock that generally models the nearby Schooner site. Bedrock below about 5 feet of stony silt consists of a 25-foot-thick layer of vitrophyre and vitrophyre breccia over felsite that extends to a depth of at least 150 feet. These two bedrock layers at the site have distinctly different physical properties, the felsite being relatively less porous and stronger in compression than the overlying vitrophyre. The felsite is massive at depth, although highly fractured, but it becomes steeply flow-layered in the upper portion. The flow layers continue across a gradational zone into the overlying vitrophyre. The resultant structure strikes about north 35 degrees east. The felsite is conspicuously jointed, and the vitrophyre contains abundant microscopic cracks.

PREFACE

The U. S. Army Engineer Nuclear Cratering Group (NCG) located five prospective sites for the Pre-Schooner II cratering experiment on the basis of published information and a field reconnaissance in mid-February 1965. Geologic mapping, seismic traversing, and core drilling programs were conducted in March 1965 by the U. S. Army Engineer Waterways Experiment Station (WES) and the NCG. After an evaluation of the results of these field programs, one area was selected as the test site by LTC W. J. Slazak and Mr. P. R. Fisher of NCG. Subsequently, the site was explored by additional drilling and geological mapping, continuing to mid-May 1965.

Geological mapping in the area was accomplished largely by Mr. R. A. Paul of NCG. Personnel of the Soils Division, WES, were responsible for the following work: (1) seismic traversing and core drilling under the direction of Mr. G. M. Leese, Expedient Surfaces Branch, and Mr. T. B. Goode, Embankment and Foundation Branch, respectively, and (2) geological observations, logging of cores, and borehole photography by Mr. R. W. Hunt and Dr. R. J. Lutton, Geology Branch. Physical tests of cores and petrographic examinations were performed at the Concrete Division, WES.

This report was prepared by Dr. Lutton and Messrs. Hunt, F. E. Girucky, and J. R. Curro, Jr., under the direction of

Messrs. W. J. Turnbull, A. A. Maxwell, J. R. Compton, W. C. Sherman, Jr., R. F. Ballard, Jr., W. L. McInnis, and W. B. Steinriede, Jr., and Dr. C. R. Kolb, all of the Soils Division, WES. Appendix D is a slightly modified version of an unpublished report by Mr. W. I. Luke, Concrete Division, WES.

Director of NCG during the conduct of this study and preparation of this report was LTC Slazak, CE. Director of WES was COL J. R. Oswalt, Jr., CE; Technical Director was Mr. J. B. Tiffany.

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TABLES

FIGURES

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows.

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
cubic yards	0.764555	cubic meters
pounds	0.45359237	kilograms
tons	907.185	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter
feet per second	0.3048	meters per second

CHAPTER I

INTRODUCTION

Project Pre-Schooner II was a chemical explosive single-charge cratering experiment in hard, dry rhyolite rock executed by the U. S. Army Engineer Nuclear Cratering Group (NCG) as a part of the joint Atomic Energy Commission-Corps of Engineers nuclear excavation research program. Pre-Schooner II was detonated on 30 September 1965 at 1709'59.2" Mountain Standard Time on Bruneau Plateau, approximately 40 miles[1] southwest of Bruneau, Idaho. The emplacement hole was at the following coordinates: Longitude W115°34'25.203", Latitude N42°24'02.943" (Modified Idaho State Coordinate System--N267,639.53; E547,783.11). The cavity, located at a depth of 71 feet, contained approximately 85.5 tons of nitromethane (CH_3NO_2) at zero time. The detonation resulted in a crater with an apparent radius of 95.2 feet, an apparent depth of 60.7 feet, and an apparent volume of 24,780 yd^3.

1.1 PURPOSE OF PROJECT

Project Pre-Schooner II, a high explosive cratering experiment, was designed as a corollary experiment to the planned nuclear event, Project Schooner. The results of this experiment will be utilized

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[1] A table of factors for converting British units of measurement to metric units is presented on page 11.

in designing Project Schooner and as data points in the continuing investigation of the engineering properties of explosion-produced craters. The rock media at the Pre-Schooner II site are essentially the same as those at the Schooner site.

1.2 SCOPE OF REPORT

This report presents the results of investigations of five predetermined areas considered for the Pre-Schooner II site and the results of investigations of the preshot condition of the rock media at the selected site. Site selection investigations included geological mapping of the five areas and vicinity, seismic surveying at each of the five areas and the Schooner site, and continuous coring of vertical boreholes at four of the five areas. Preshot investigations of the selected Pre-Schooner II site included the boring and logging of 13 core holes, physical testing of representative cores, and continuous photographing of selected holes with a borehole camera.

1.3 SITE SELECTION CRITERIA

The five prospective Pre-Schooner II sites (Areas 1 through 5) were chosen by NCG for investigation on the basis of the following criteria: (1) proximity to the Schooner site, (2) rock similar to that at the Schooner site, (3) minimum overburden, (4) reasonably flat topography, and (5) topography favorable for scientific photography.

1.4 LOCATION AND ACCESS

The five areas examined lie on broad, semiarid terrain south of the Snake River Valley in eastern Owyhee County in south-central Idaho. This general area is known as the Bruneau Plateau. Access to the site from each of the communities of Bruneau, Glenns Ferry, and Buhl (Figure 1.1) is by approximately 60 miles of paved, graveled, and dirt roads.

The land is commonly leased from the Bureau of Land Management by sheepmen and cattlemen for summer grazing. The closest cultivated land is near Grasmere, 13 miles west of the site across the Bruneau River. Nearby dwellings, occupied at least part of the year by cattlemen, are found at Winter Camp Ranch and Clover Flat Ranch on East Fork Bruneau River and at Indian Hot Springs on West Fork Bruneau River.

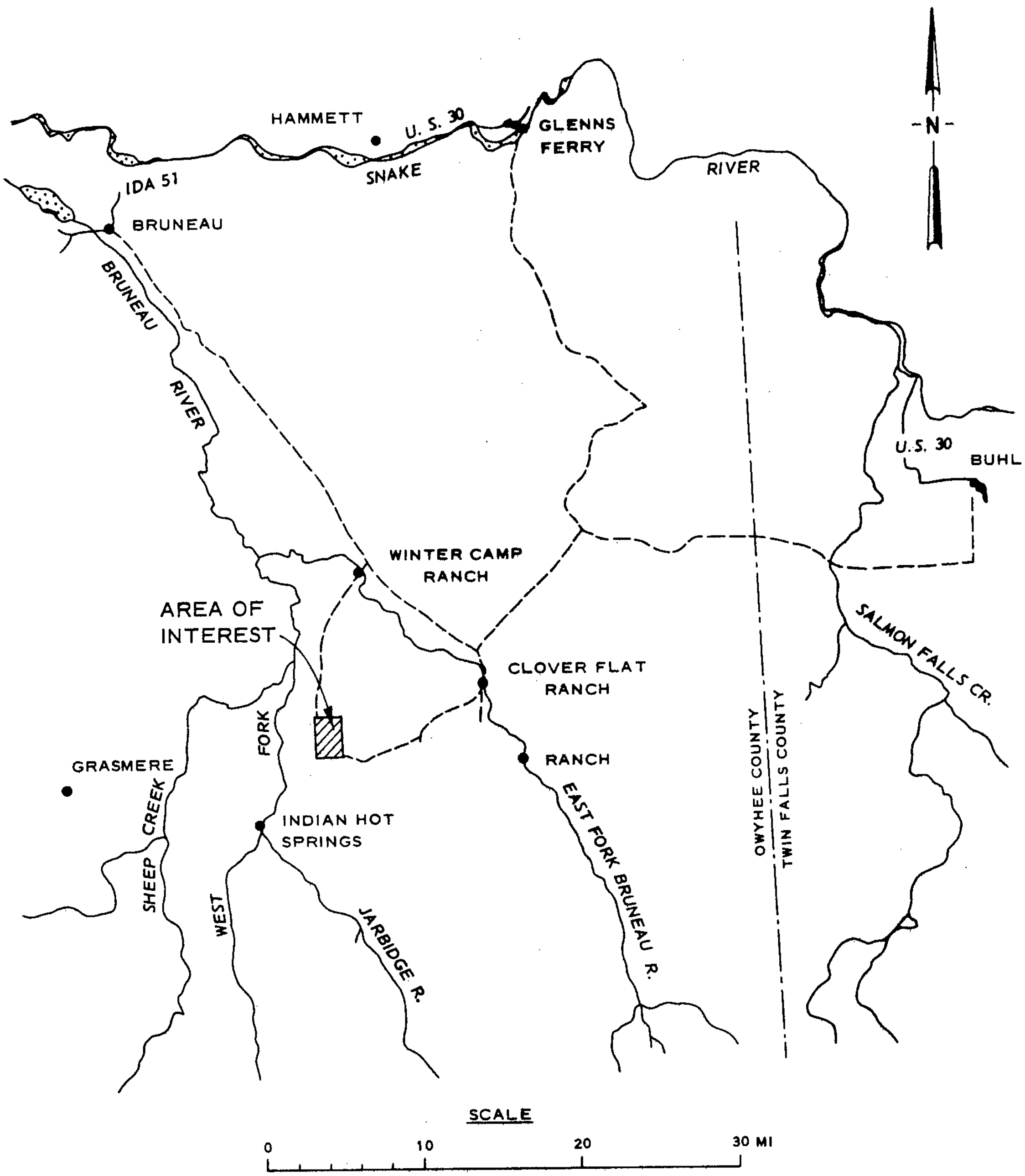


Figure 1.1 Map of south-central Idaho showing location and access to the Pre-Schooner II site.

CHAPTER 2

SEISMIC INVESTIGATIONS FOR SELECTION OF PRE-SCHOONER II SITE

Two surface-refraction seismic traverses at right angles to each other were run at each of the five prospective Pre-Schooner II sites (Areas 1 through 5), and a single seismic traverse was run at the Schooner site. A description of the surface-refraction seismic traverses is presented in Table 2.1. Subsurface data were obtained by means of continuously cored vertical borings located at the intersections of seismic traverses at Areas 1, 2, 3, and 4.

2.1 EQUIPMENT AND PROCEDURES

The equipment used for the seismic survey was a portable, 12-channel Century refraction seismograph equipped with a dry developing recorder that gives a permanent record.

Each seismic traverse consisted of several segments because the seismic cable was too short to cover the traverse with only one positioning. Geophone spacing varied (see Figure 2.1), and the segment lengths varied from 475 to 600 feet, depending on this geophone spacing. There was some overlapping of the segments on each traverse, providing some reversal data. However, geophone spacing was not close enough to delineate the overburden accurately.

Charges were detonated in holes at even-numbered stations spaced at 200-foot intervals along each seismic traverse at Areas 1 through 5. The charge locations for the traverse at the Schooner site were all at the east end of the line. Charges consisted of several 1/2-pound sticks of 40 percent nitroglycerin dynamite, with the number of sticks depending upon the shot depth, length of single segment, and anticipated subsurface material.

2.2 METHOD OF DATA REDUCTION

After the charge had been detonated and the response of the geophones had been recorded, the time intervals required for the compression wave to travel from the shot point to each successive geophone were determined from the records. With the distance from the shot point to the first geophone and the spacing of the successive geophones known, time-distance curves were plotted (Figure 2.2). The reciprocal of the slope of the line indicates the velocity of the wave through the particular medium. A change in slope of the line indicates a change in velocity of the wave at a given depth (D_1), which can be calculated by the following relation from Reference 1:

$$D_1 = \frac{X_1}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

Where: X_1 = slope intersection distance (in feet) (i.e. distance from origin along the abscissa to point at which the slopes intersect)

V_1 = velocity (in feet per second) in the medium in which the first slope was produced

V_2 = velocity (in feet per second) in the medium in which the second slope was produced

If a third velocity is encountered, the relation for calculation (Reference 1) of the second depth (D_2) from the surface is:

$$D_2 = \frac{5}{6} D_1 + \frac{X_2}{2}\sqrt{\frac{V_3 - V_2}{V_3 + V_2}}$$

Where: X_2 = distance (in feet) from origin to point at which second charge in slope occurs

V_3 = velocity (in feet per second) of the third medium

The velocities and depths determined by this method can then be represented as velocity profiles.

On many of the time-distance plots, a delay was evident in the compression wave arrival times from a particular interface. This was caused by a low-velocity material underlying a high-velocity material. Therefore, depths to interfaces below this low-velocity medium could not be computed from the conventional equations from Reference 1 because they would be erroneously large. A procedure was utilized to provide a correction for the depths computed from the standard equations (Reference 2). Seismic velocities at Area 1 (Figure 2.3) were not affected by the low-velocity material. However, the velocity profile for Line 2, Area 2, shown

in Figure 2.4, shows an example of a low-velocity zone underlying a high-velocity zone, 2,700 to 3,000 ft/sec and 4,000 to 8,000 ft/sec, respectively. The conventional calculations for the depth to the third zone (12,500 ft/sec) give the apparent depth shown in Figure 2.4. The corrected depth to the 12,000-ft/sec zone was somewhat shallower.

In constructing the profiles of the seismic data from Areas 1 through 5, an arbitrary reference surface was used to eliminate or minimize the large differences in elevation of each area. For each area, all data were referenced to a selected horizontal plane called the datum plane. Correcting all data to the datum plane gives a true indication of the dip of the subsurface beds, and all depths to the subsurface interfaces are referenced from the datum plane. To obtain the depth from a particular point on the ground surface to an interface, an addition or subtraction is made to the depth from the datum plane to the interface. This addition or subtraction consists of the depth from the point on the ground surface to the datum plane. If the point on the ground surface is above the chosen datum plane, a true depth related to ground surface can be determined by raising the elevation of the indicated interface a similar amount.

2.3 DATA ANALYSIS

The profiles of the seismic data are illustrated in Figures 2.3 through 2.7. Although the velocity changes shown on the

profiles do not usually coincide with changes in rock types indicated by the borings, this situation does not necessarily indicate a lack of correlation. Velocity changes indicated by refraction seismic data are dependent on the physical characteristics of the media. Therefore, factors such as weathering and extensive fracturing within a single rock type will cause a velocity change that could mask a lesser change between rock types.

The data recorded on Line 2 at Area 5 (Figure 2.7) were collected with some difficulty and are probably not very reliable.

The velocities of the upper 8 to 10 feet of material at all sites are approximations based on the few data points provided by the relatively long geophone spacings and comparison of the data obtained from the core samples.

TABLE 2.1 DESCRIPTION OF SURFACE-REFRACTION SEISMIC TRAVERSES

NA, not applicable.

Location		Traverse		Geophones			Shot Holes[b]			Station at Seismic Traverse Intersection	Coordinates[d] at Seismic Traverse Intersection	
Area	Line	Bearing from Sta 0+00[a]	Total Length	No. Spaced at 25 ft	No. Spaced at 50 ft	Coverage for Each Shot	No.	Depth	Charge[c]		North	East
		degree	feet			feet		feet				
1	1	S	1,000	2	10	550	6	5	2	7+00	274,030	550,360
1	2	E	1,400	5	7	475	8	5	2	7+00	--	--
2 2	1	S39W	1,200	5	7	475	7	5	2	6+00	267,641.8	547,524.5
2 2	2	S51E	1,400	5	7	475	8	5	2-3	7+00	--	--
3 3	1	S16W	2,200	0	12	600	12	6	2	14+00	267,090	556,470
3 3	2	S75E	1,400	5	7	475	8	6	2	7+00	--	--
4 4	1	N22E	1,600	0	12	600	9	10	2	10+00	271,450	555,430
4 4	2	S70E	1,400	5	7	475	8	5	2	7+00	--	--
5 5	1	N81E	1,400	5	7	475	8	5	2	7+00	280,360	549,110
5 5	2	S10E	1,400	5	7	475	8	5	1-3	7+00	--	--
Schooner	--	W	2,375	5	7	475[e]	1	5	3	NA	272,190[f]	553,570[f]
	--	--	--	0	12	600	2	15	6-9	NA	--	--
	--	--	--	--	--	--	2	18	12-15	NA	--	--

a Traverse bearings are approximate at all locations except Area 2.
b All shot holes were spaced at 200-foot intervals with the exception of those at the Schooner site.
c Stated as the number of 1/2-pound sticks of 40 percent nitroglycerin dynamite.
d Idaho State Coordinate System. Coordinates are approximate for all locations except Area 2.
e Only one line was run with this geophone spacing; four lines were run with the alternate geophone spacing.
f At Sta 2+00, coordinates of Bruneau 2 boring.

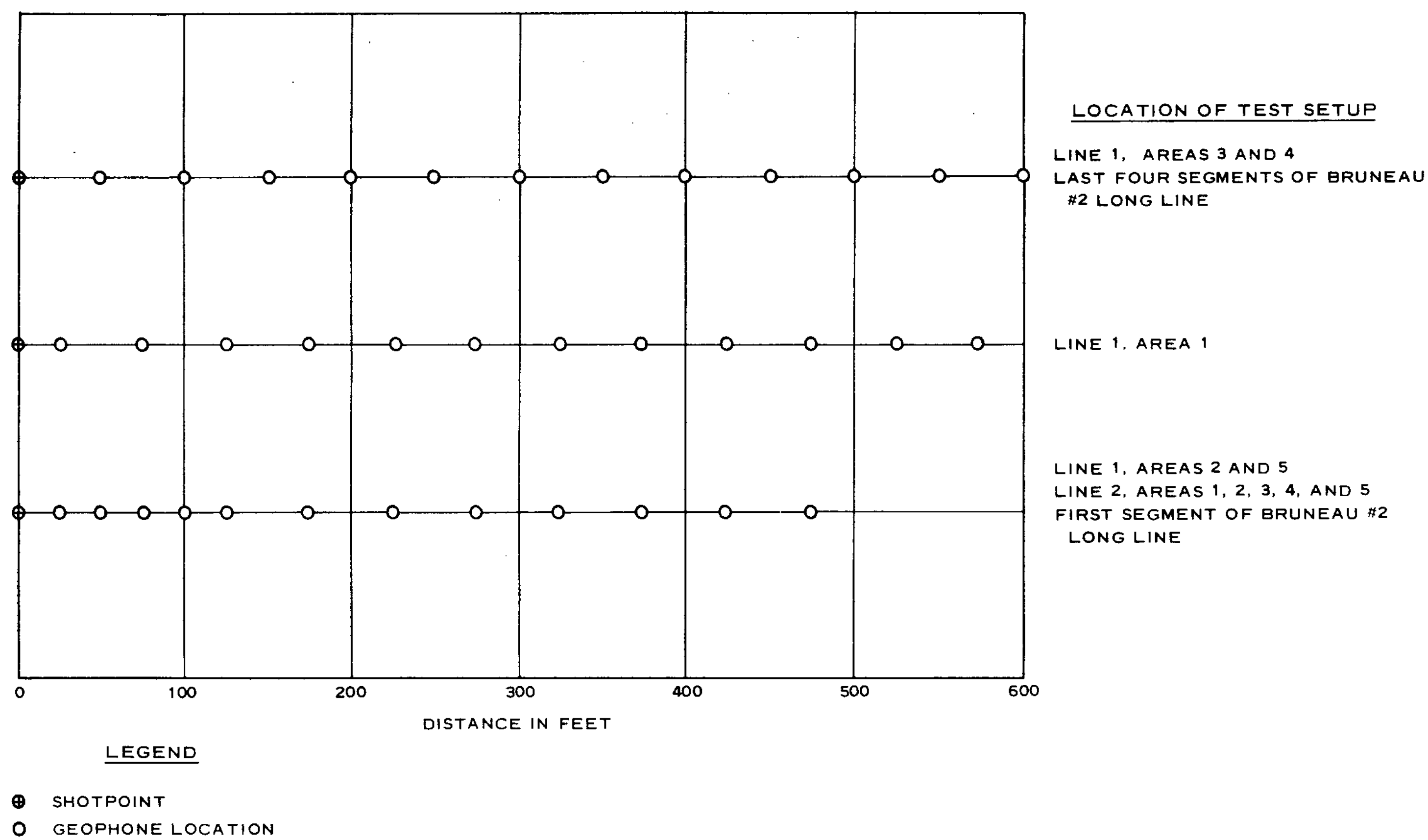


Figure 2.1 Geophone spacing employed at prospective Pre-Schooner II site and Schooner site.

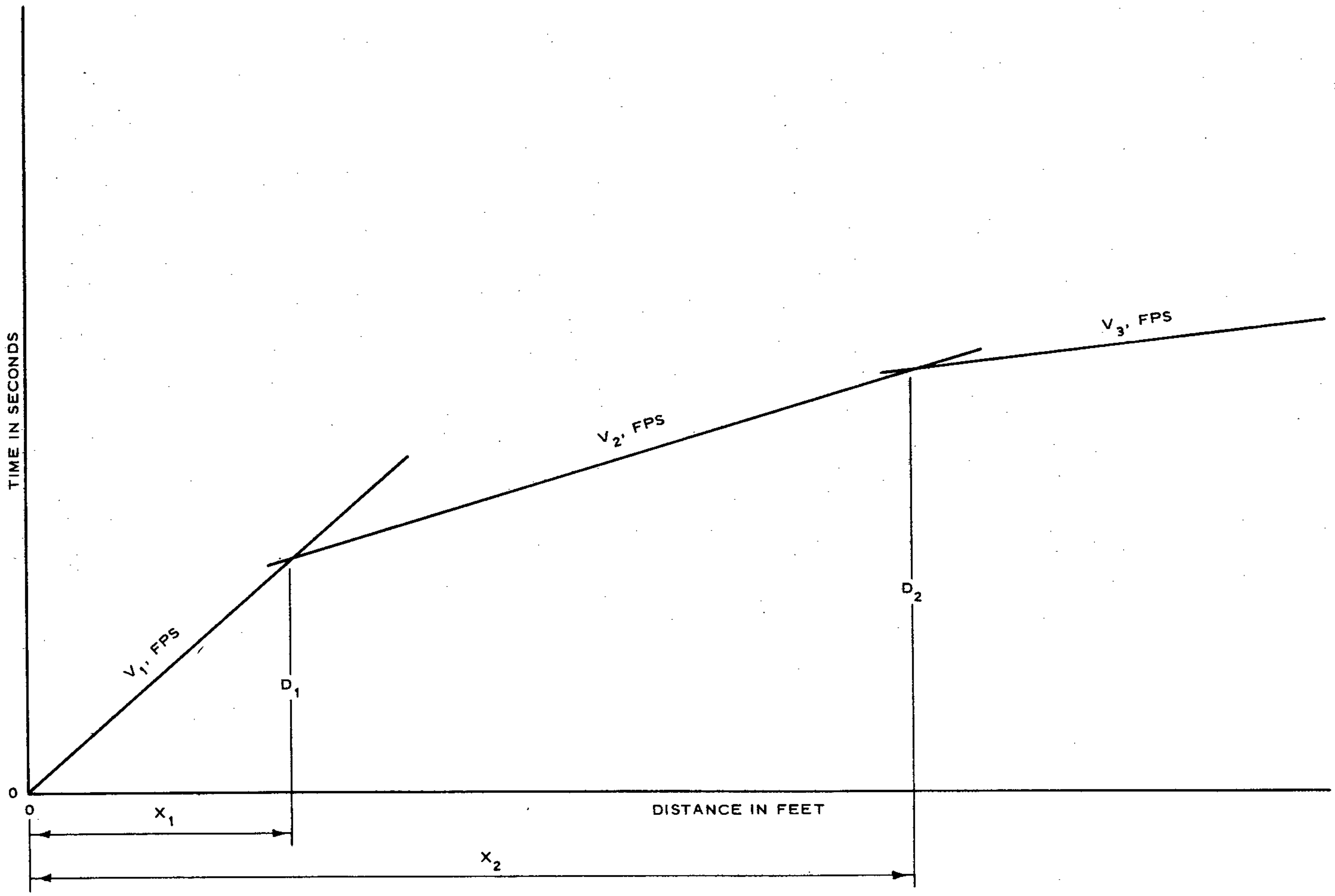


Figure 2.2 Example of a typical time-distance plot of seismic traverse data.

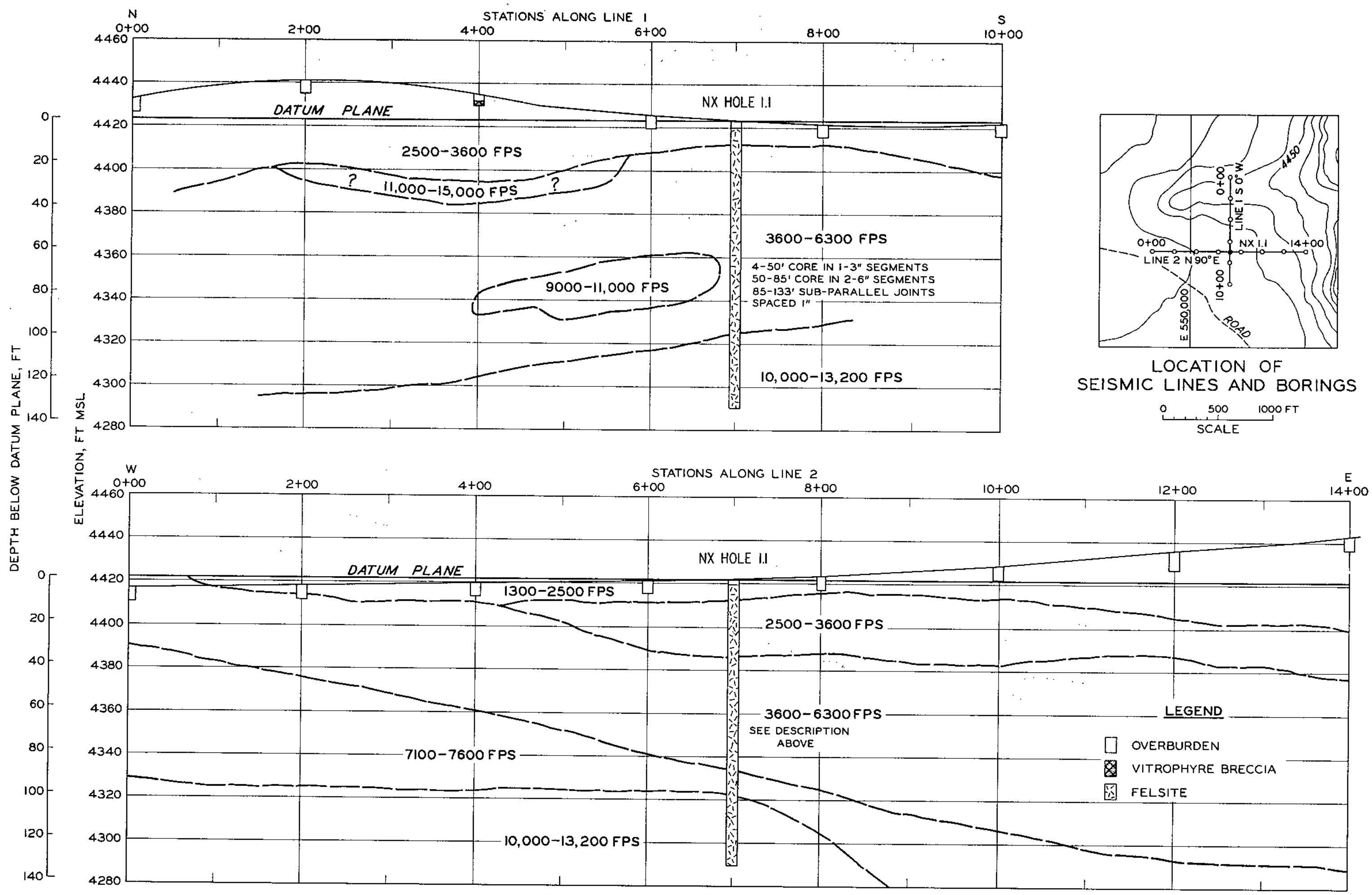


Figure 2.3 Seismic velocity profiles at Area 1.

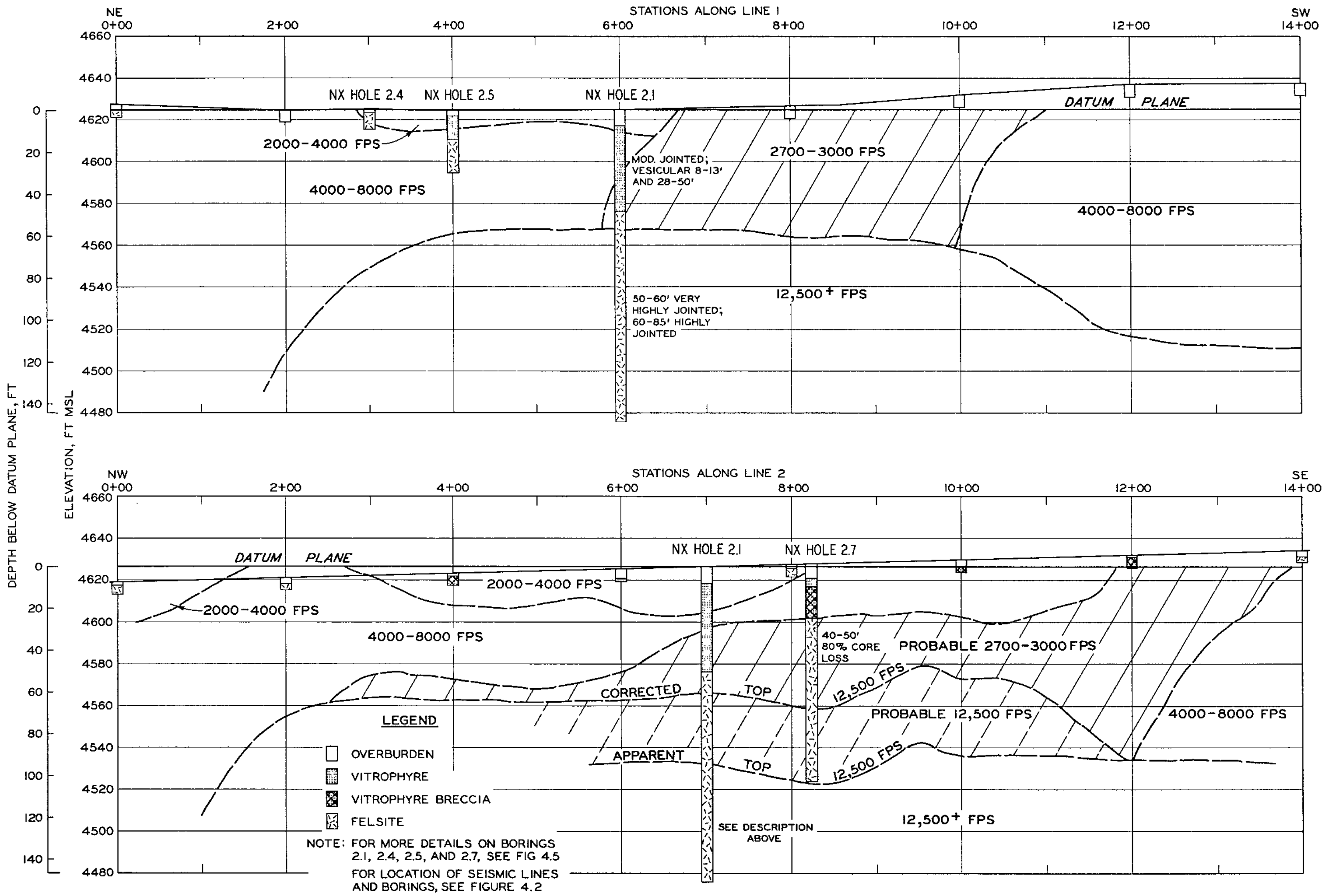
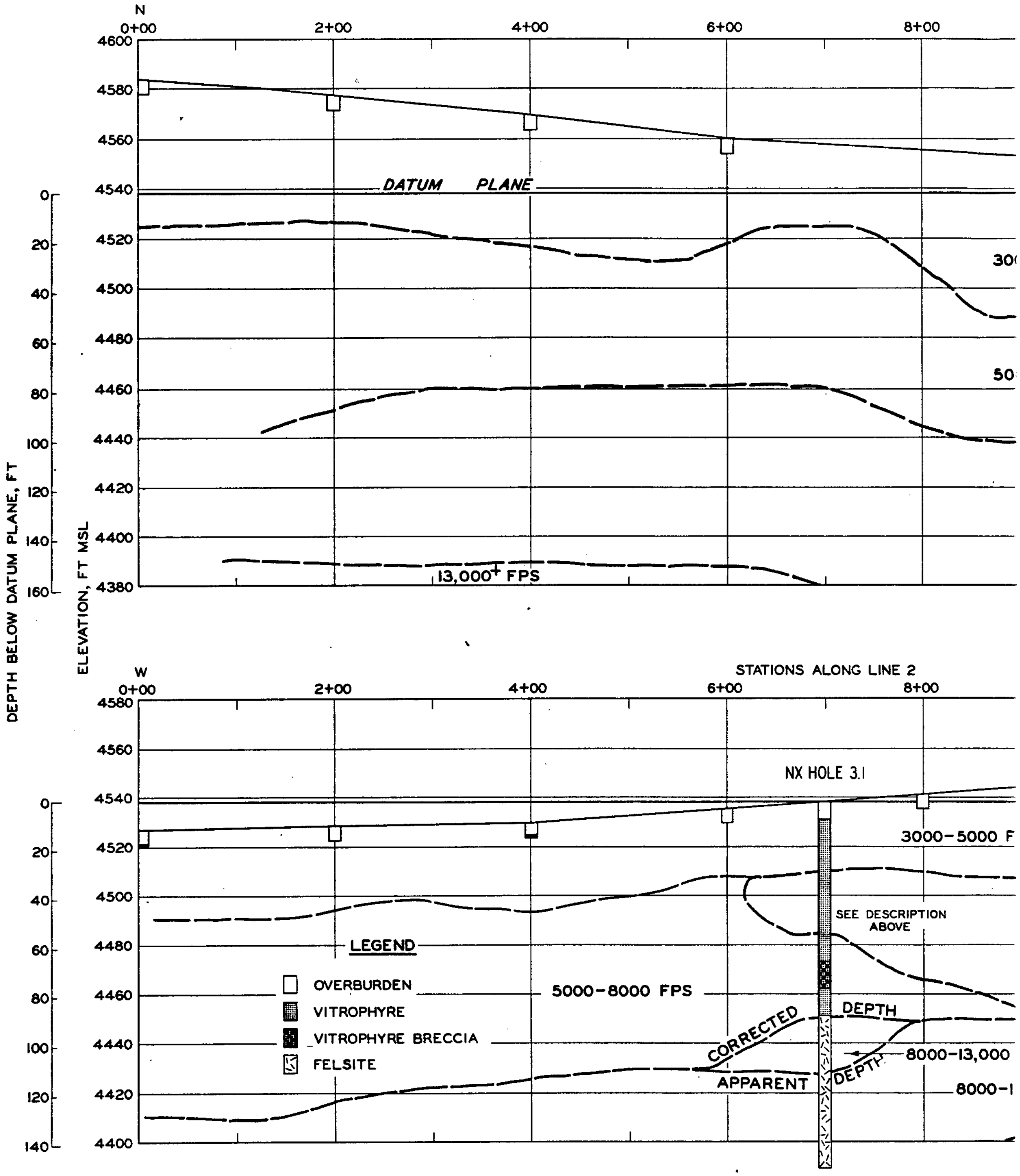
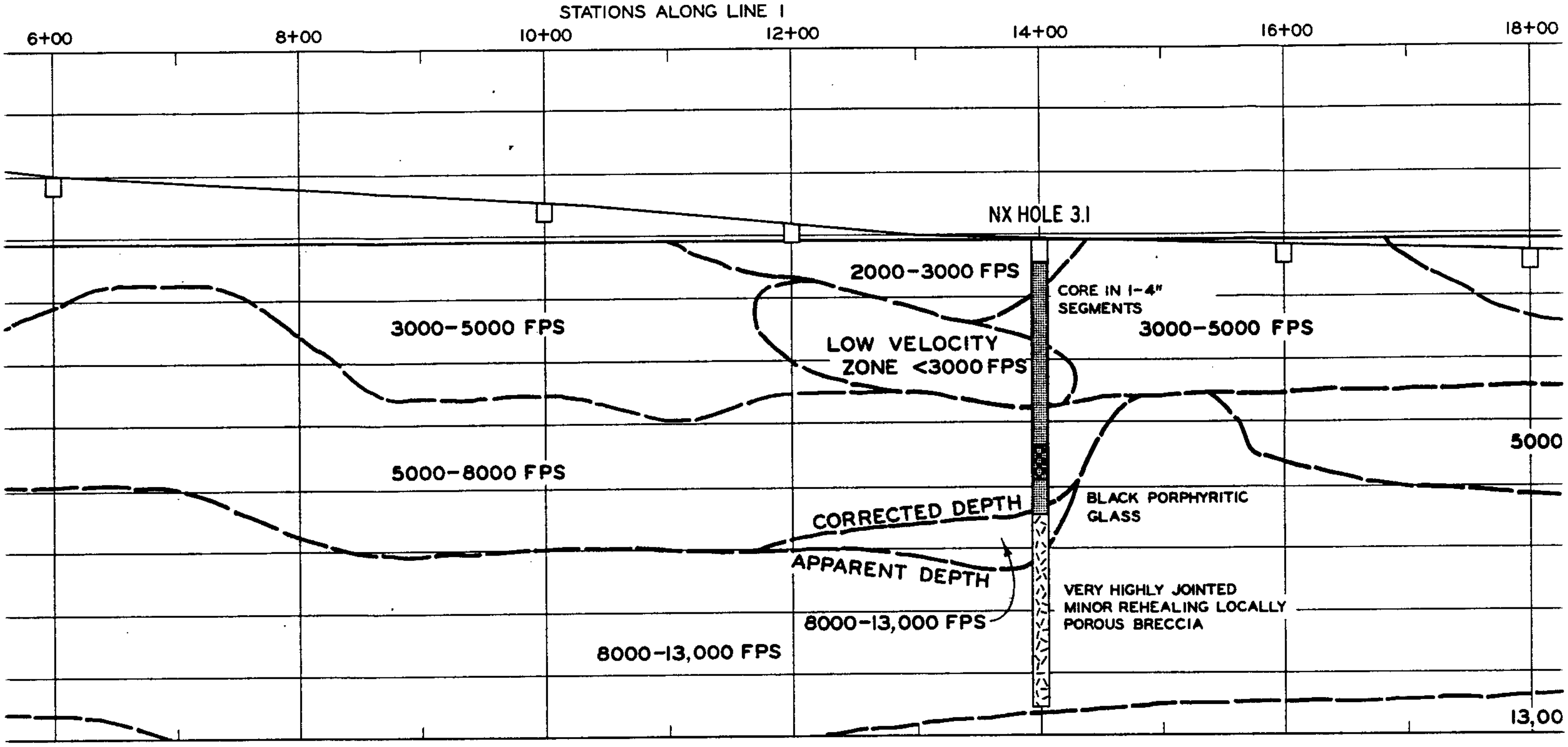


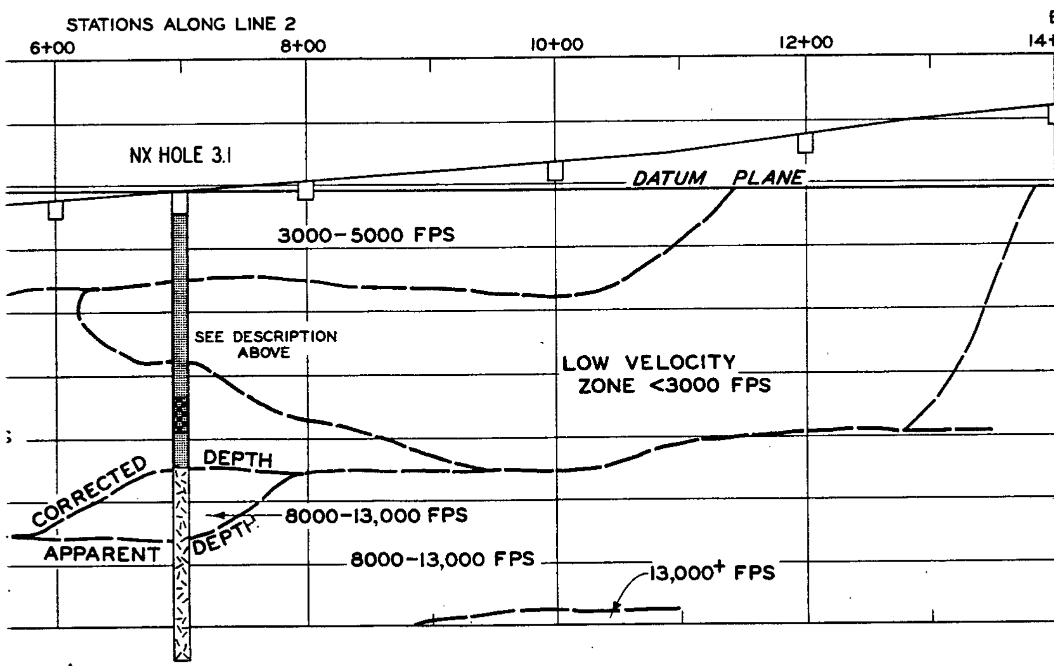
Figure 2.4 Seismic velocity profiles at Area 2 (Pre-Schooner II site).



N
0+00
2+00
4+00
6+00
8+00
DATUM PLANE
30
50
13,000+ FPS
DEPTH BELOW DATUM PLANE, FT
ELEVATION, FT MSL
W
STATIONS ALONG LINE 2
NX HOLE 3.1
3000-5000 F
SEE DESCRIPTION ABOVE
LEGEND
OVERBURDEN
VITROPHYRE
VITROPHYRE BRECCIA
FELSITE
5000-8000 FPS
CORRECTED
DEPTH
APPARENT
DEPTH
8000-13,000
8000-1

Figure 2.5. Se





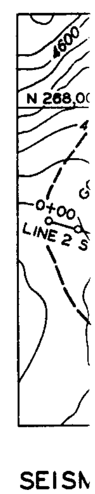
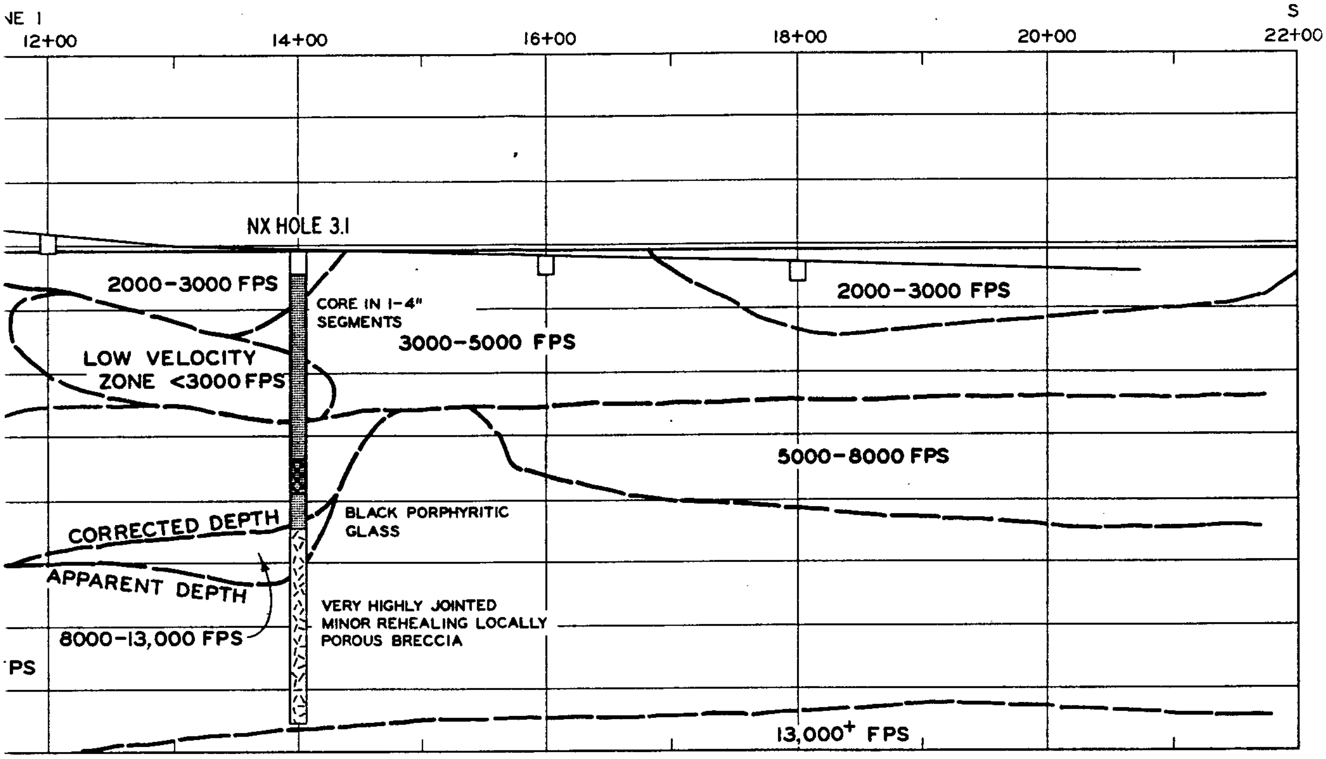
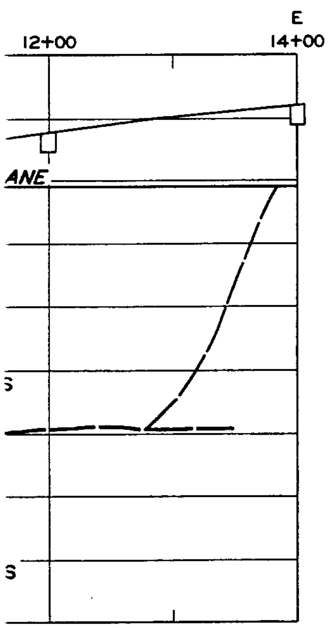
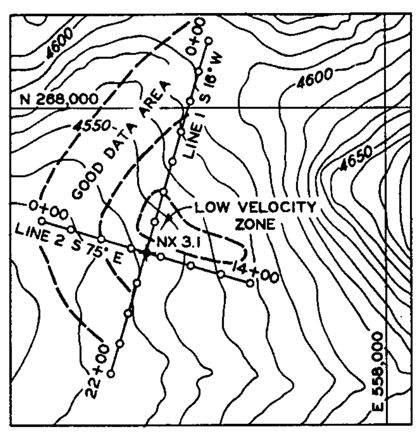


Figure 2.5. Seismic velocity profiles at Area 3.

2







LOCATION OF
SEISMIC LINES AND BORINGS

0 500 1000 FT
SCALE

es at Area 3.

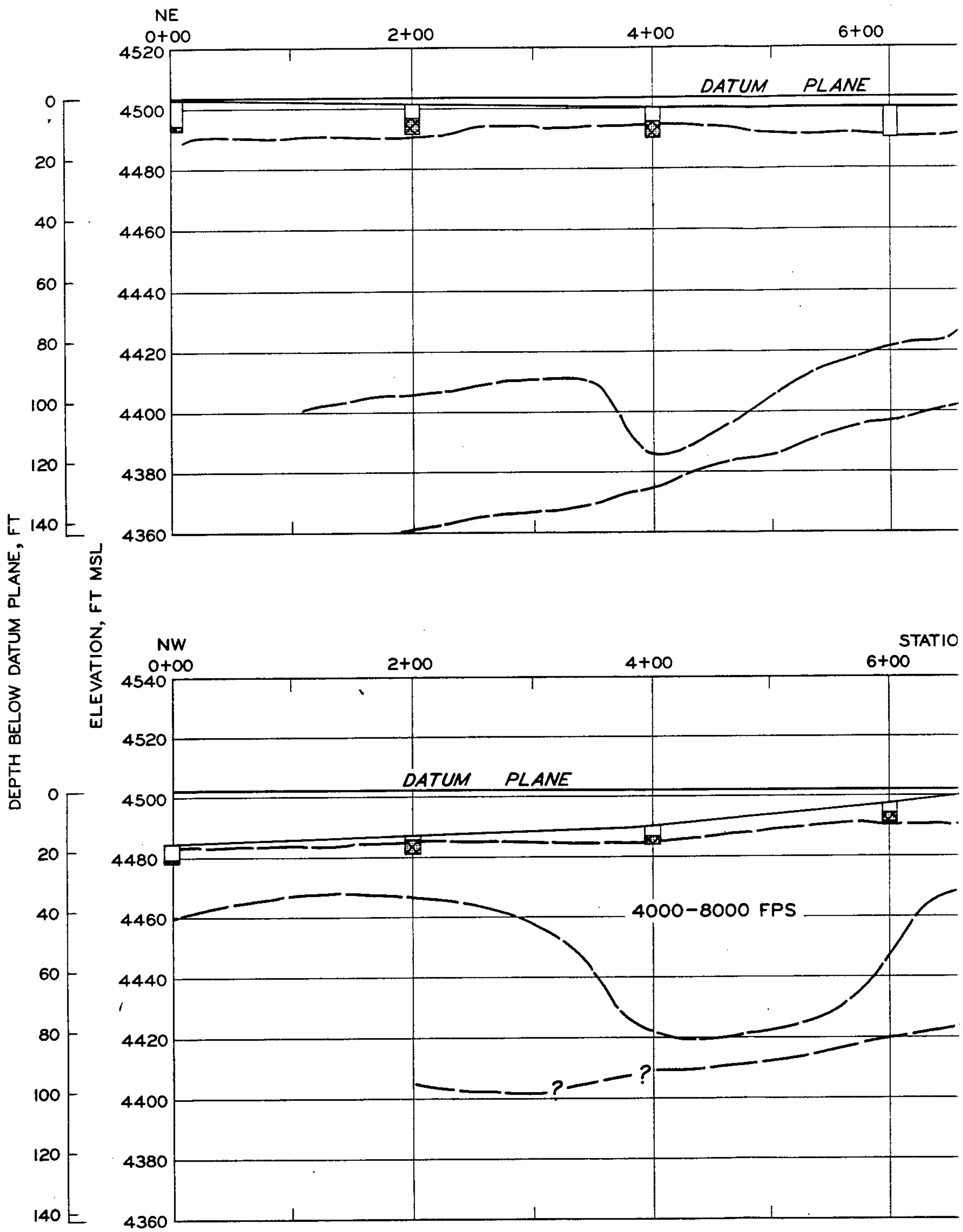


Figure 2.6 Seismic velc

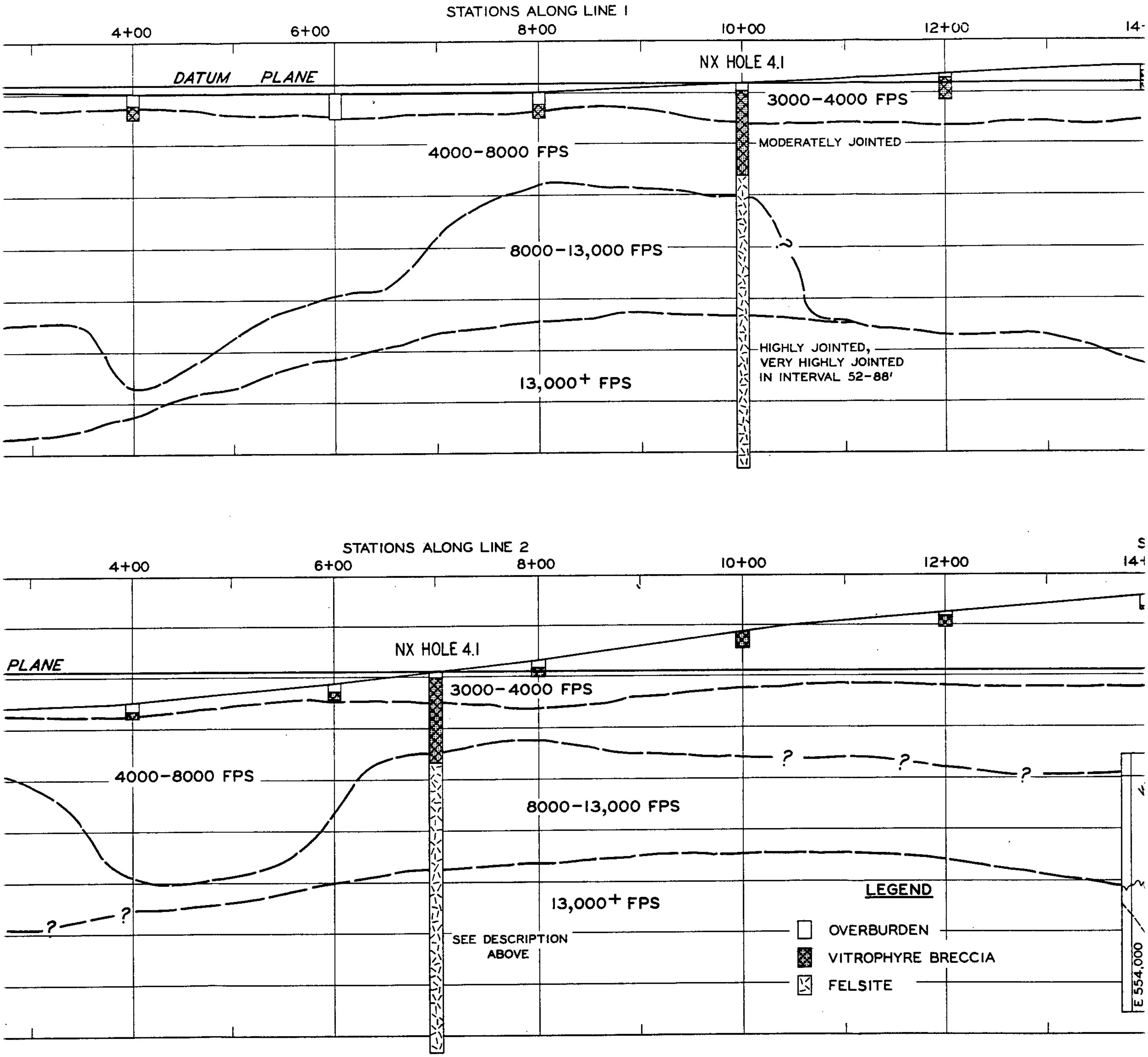
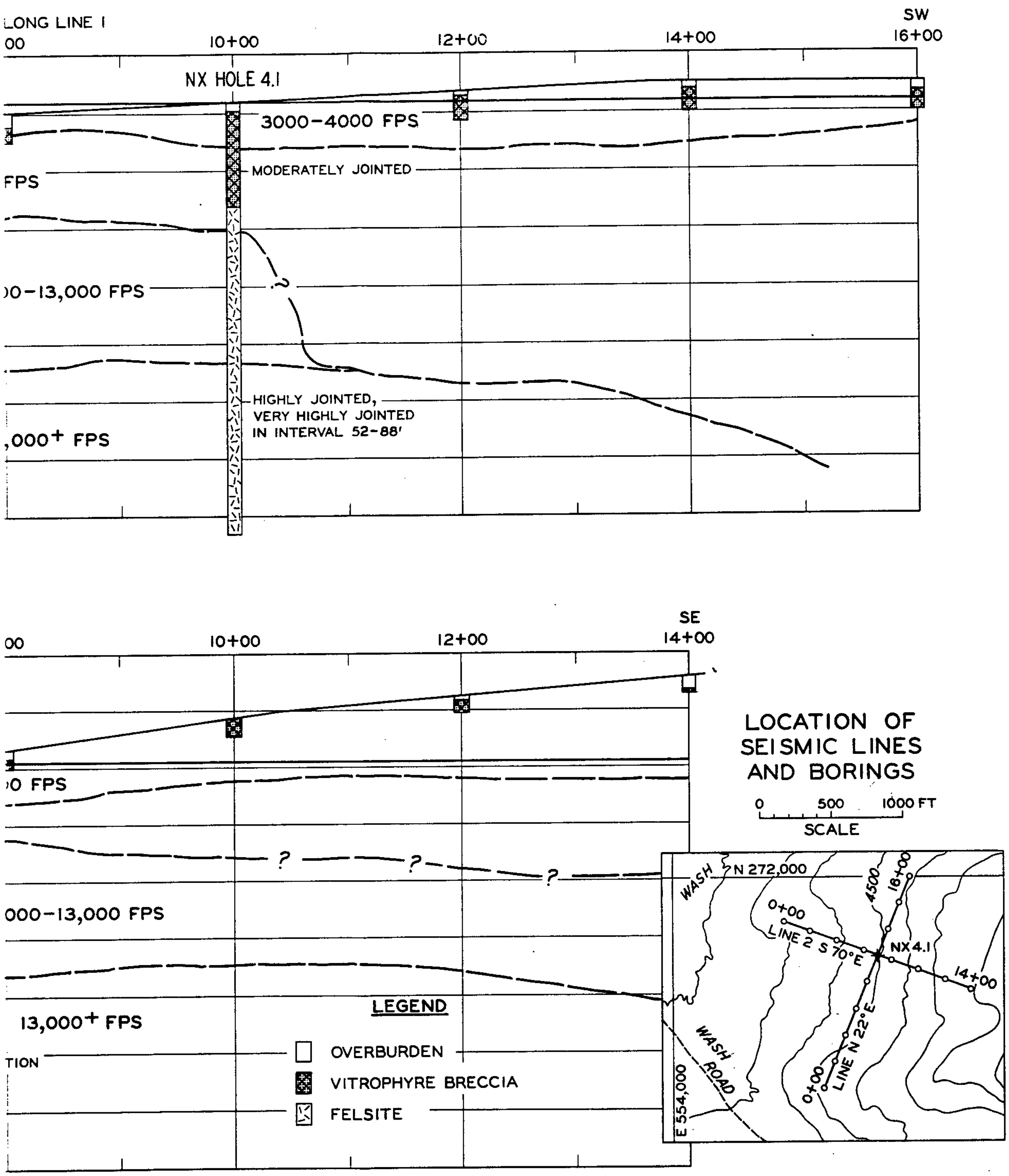


Figure 2.6 Seismic velocity profiles at Area 4.



LONG LINE I
00
10+00
12+00
14+00
SW
16+00
NX HOLE 4.1
3000-4000 FPS
MODERATELY JOINTED
FPS
)0-13,000 FPS
HIGHLY JOINTED,
VERY HIGHLY JOINTED
IN INTERVAL 52-88'
,000+ FPS
00
10+00
12+00
SE
14+00
)0 FPS
?
?
?
000-13,000 FPS
13,000+ FPS
TION
LEGEND
OVERBURDEN
VITROPHYRE BRECCIA
FELSITE
LOCATION OF
SEISMIC LINES
AND BORINGS
0
500
1000 FT
SCALE
WASH
N 272,000
4500
16+00
0+00
LINE 2 S 70°E
NX 4.1
14+00
LINE N 22°E
0+00
WASH
ROAD
E 554,000

s at Area 4.

3

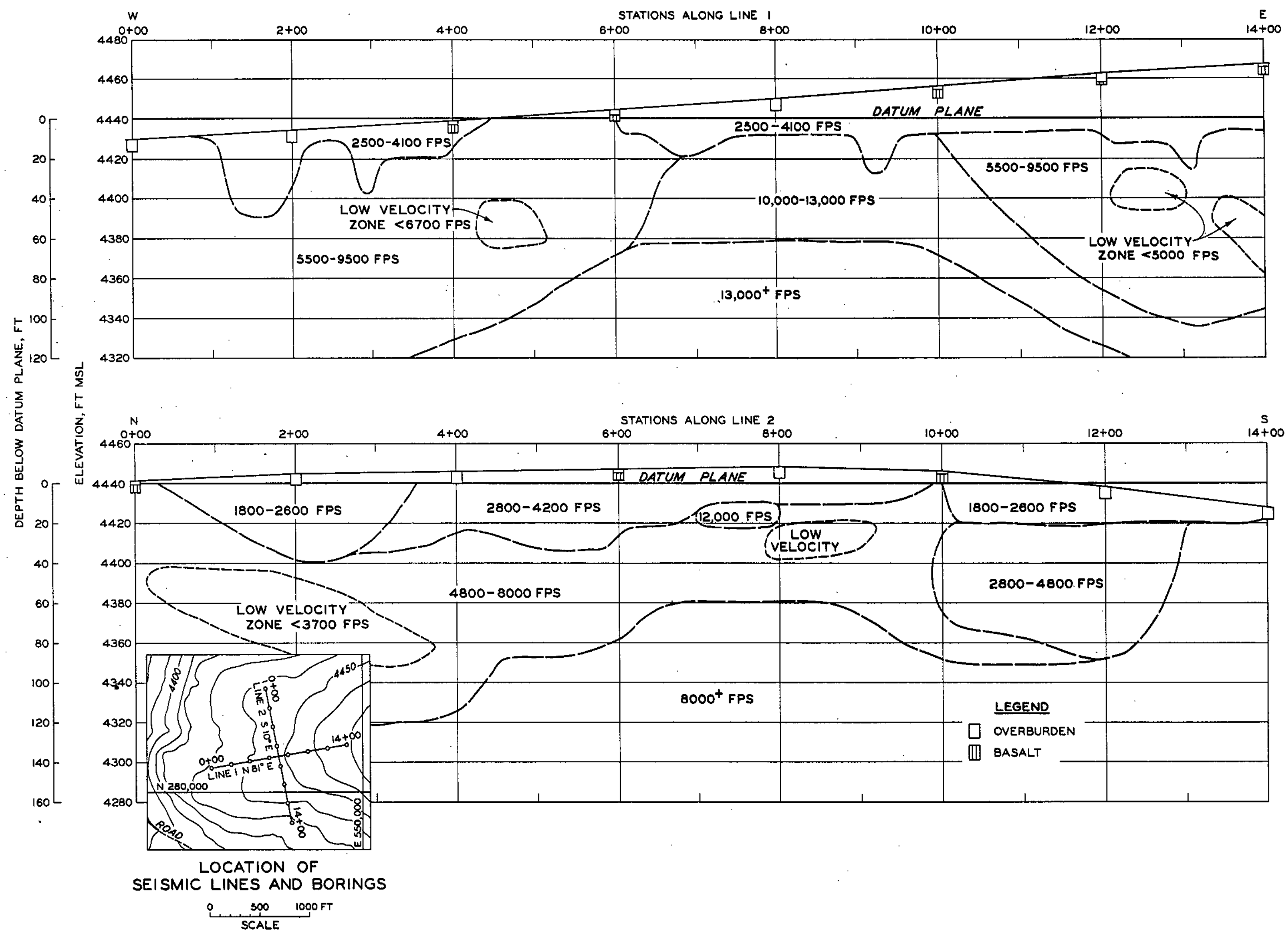


Figure 2.7 Seismic velocity profiles at Area 5.

CHAPTER 3

GEOLOGICAL EVALUATION OF AREAS FOR SELECTION OF PRE-SCHOONER II SITE

Geological examinations of five localities near the Schooner site were made in conjunction with the seismic examination to facilitate choosing the Pre-Schooner II site. Major types of bedrock recognized are felsite, vitrophyre and closely related breccia, and basalt. About 5 feet of aeolian silt mixed with loose rock blankets the bedrock.

Oldest rocks exposed in the vicinity are the Idavada volcanics (Figure 3.1). The Bruneau 2 hole at the Schooner site (Reference 3) penetrated almost 1,400 feet, consisting of mostly silicic volcanics, of this unit without reaching older formations, and over 700 feet of the Idavada is exposed in Bruneau Canyon 2 miles west of the Schooner site. In spite of the fact that welded tuff has been emphasized in descriptions of the Idavada volcanics (Reference 4), lavas prevail in this area.

The rather simple picture of stratigraphy at each of the possible sites becomes complex when attempts are made to integrate stratigraphy at all possible sites and at the Schooner site. The difficulty involves explaining the great range in elevation (600 feet) of the vitrophyre-felsite contact throughout the area. Several possible explanations can be offered: (1) an ancient erosion

surface, (2) cyclic repetition of the stratigraphic sequence, (3) relief on an immense lava flow, (4) faulting, or (5) a combination of one or more of the foregoing. Observations made during this investigation tend to support the third explanation above.

3.1 AREA 1

Area 1 flanks a low ridge of felsite that extends from the prominent felsite knob northwest of the Schooner site (Figure 3.1). The distance from Bruneau 2 hole at the Schooner site to Hole 1.1 at the center of Area 1 is about 3,800 feet. Float rock on the ridge suggests that felsite underlies the shallow silt cover except in an area of vitrophyre about 300 feet in diameter just northwest of Hole 1.1. At the hole, felsite was penetrated below the overburden, and it continues with no change to the bottom depth of 133 feet. The rock is cut by a prominent set of closely spaced joints.

The seismic velocities of the felsite increase with depth on Line 2 (Figure 2.3) from 1,300 to 2,500 ft/sec in the surface layer to 10,000 to 13,200 ft/sec in the felsite at 100 feet and deeper. On Line 1, however, a discontinuous high-velocity zone may be present in the felsite at about a 20-foot depth. The existence of this zone is open to question as nothing was seen in the core from NX Hole 1.1 to suggest its extension through the boring.

Because the area lacks an extensive layer of vitrophyre, it offers a poor analog to the Schooner site. For this reason, it was rejected by NCG as the test site.

3.2 AREA 2

Area 2 was chosen by NCG as the Pre-Schooner II site, and detailed information concerning the area is presented in Chapter 4.

3.3 AREA 3

This area, which lies about 5,800 feet southeast of Bruneau 2 hole, occupies a valley between ridges of felsite on the north and south. The rocks encountered below 8 feet of silt overburden are vitrophyre, vesicular vitrophyre, and vitrophyre breccia to a depth of 88 feet and felsite from there to at least 150 feet.

Seismic velocity profiles and results of drilling are shown in Figure 2.5. The nature of the seismic discontinuities is not clear from rock cores. Due to the presence of a low-velocity layer from 30 to 60 feet (Boring NX 3.1), the apparent velocity contour computed to lie at 110 feet should be raised to 88 feet. It thus correlates with the vitrophyre-felsite contact.

Area 3 was eliminated from consideration as the Pre-Schooner II site because of the excessive thickness of vitrophyre and the presence of a major core-loss zone at a depth of 55 to 80 feet where excavation for explosive emplacement would be required.

3.4 AREA 4

Area 4 lies in the broad valley occupied by the Schooner site 2,000 feet to the northwest. Patches of vitrophyre breccia outcrop in various places over an area at least 500 feet in diameter; and in Hole 4.1, the breccia persists to a depth of 36 feet (Appendix A). Glassy felsite continues from 36 feet to 52 feet where it grades to felsite. The seismic discontinuities indicated on the two profiles (Figure 2.6) correlate approximately with the geologic contacts. Thus, the velocity break at about 35 feet (Boring NX 4.1) correlates with the top of the felsite.

This area was eliminated from further consideration as the Pre-Schooner II site because it is too near the Schooner site, and it has an excessive core-loss zone in the interval from 15 feet above to 10 feet below the center of the emplacement cavity (55- to 80-foot depth).

3.5 AREA 5

Area 5 lies about 9,300 feet northwest of the Bruneau 2 hole near the road from Winter Camp. Bedrock under about 5 feet of silt is basalt. Only seismic exploration was undertaken at this site since the site media do not adequately model the media at the Schooner site.

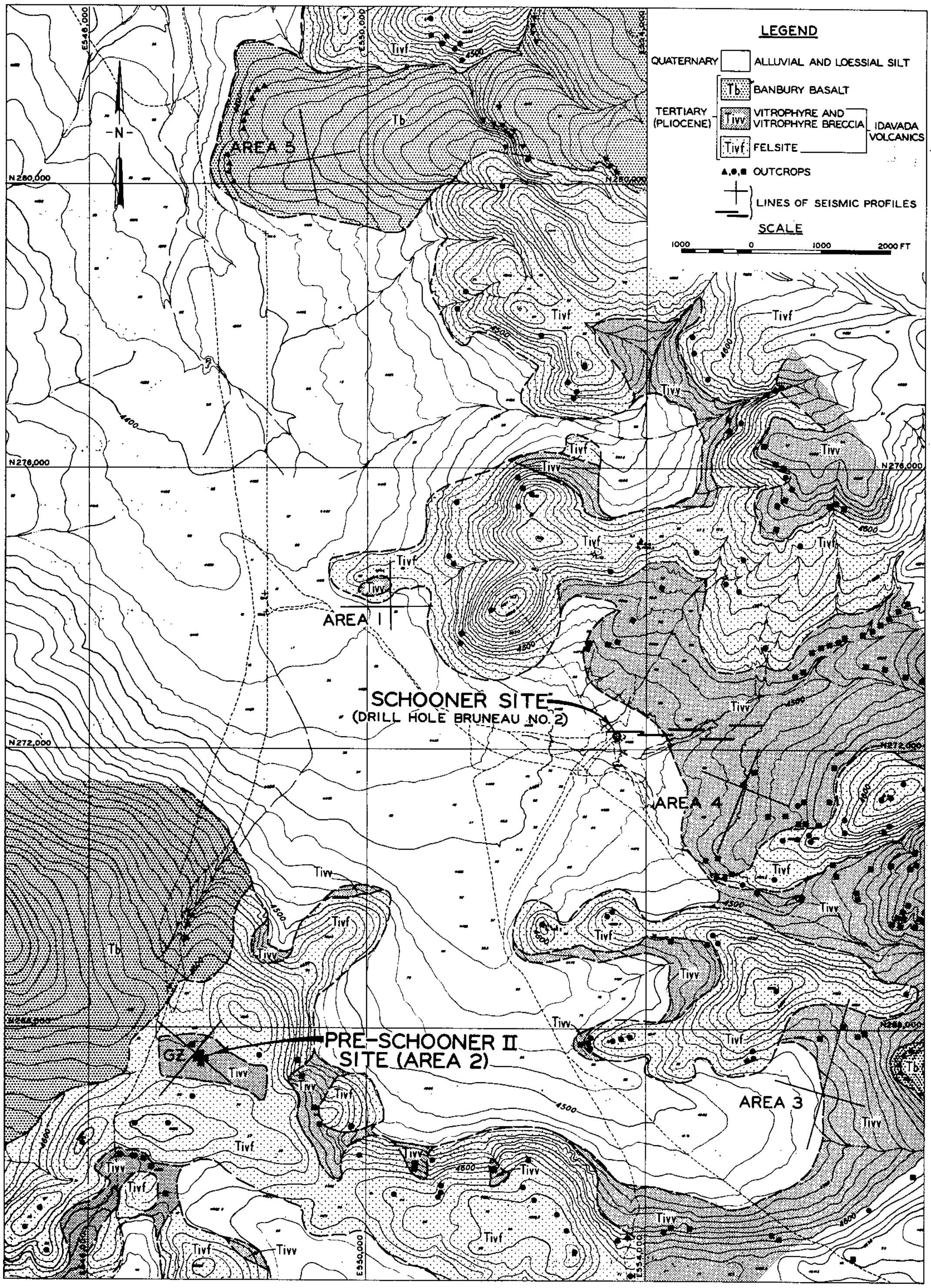


Figure 3.1 Geological map of vicinity of Pre-Schooner II and Schooner sites.

CHAPTER 4

GEOLOGICAL INVESTIGATIONS OF PRE-SCHOONER II SITE

Area 2 was selected as the Pre-Schooner II site by NCG for several reasons: (1) among the available areas, it presented the best stratigraphic analog to the Schooner site; (2) rock at shot depth was reasonably competent; (3) the site is readily accessible; and (4) it is far enough from the Schooner site not to interfere with possible Schooner construction activities. Hole 2.7 intersected the intended zero point at this site.

4.1 TOPOGRAPHY

The selected site occupies a relatively flat area on an east-west trending ridge approximately 7,600 feet southwest of the Schooner site. The tops of low knobs of resistant felsite lie at distances of 750 and 1,300 feet to the northeast and southwest, respectively. The flat at the site slopes down about 2 percent to the northwest. To the east, the flat ends at a relatively steep slope of about 10 percent that drops 100 feet in elevation. Except for this slope reversal, the topography at the Pre-Schooner II site appears to model that at the Schooner site quite closely (Figure 4.1).

4.2 STRATIGRAPHY AND PETROGRAPHY

Cores from the 13 holes (Figure 4.2) drilled to explore the

Pre-Schooner II site, supplemented by those of the previous holes in other areas, allowed a detailed field classification of the rock. Three general lithologic types were identified: felsite, vitrophyre, and vitrophyre breccia. Gradational lithologic subtypes also recognized in the field were lithoidal vitrophyre and glassy felsite.

In the discussion of physical properties (Chapter 5), both vitrophyre and felsite are further divided by structural characteristics into layered and homogeneous variants. A vesicular vitrophyre is also recognized.

The laboratory petrographic analysis classified all the rock types as porphyritic rhyolite vitrophyre on the basis of mineralogic content and texture (Appendix D). However, because of the distinct visual differences and differences in physical properties, the field nomenclature is retained.

A sequence of these lithologic types thought to be a single flow at least 700 feet thick is revealed in the walls of Bruneau Canyon 2 miles to the west.

At the site the felsite invariably underlies the other types, but the breccia can be found above and/or below the vitrophyre. Silt overburden 0 to 10 feet thick (Figure 4.3) blankets the site.

4.2.1 Vitrophyre. The typical vitrophyre contains 10 to 20 percent euhedral to subhedral, oligoclase phenocrysts in a black glass groundmass. The refractive index of a sample of the glass

(Appendix D) indicates a high silica content in the range of rhyolite. However, the bulk composition of the rock may fall in the range of quartz latite. White powder that forms on the core after wetting and drying suggests that alkali or alkaline earth components are easily leached from the glass by water.

Perlitic cracks are recognized on oxidized joint surfaces and in thin sections from their closely spaced, curved traces. The vitrophyre is commonly colored red adjacent to joints and vesicles, presumably by oxidation of the iron. Bulk dry specific gravities of samples of massive vitrophyre that are relatively low in vesicles range from 2.34 to 2.40.

The vitrophyre and closely related vitrophyre breccia are complexly interlayered in a bed that varies greatly in thickness (Figure 4.4) but averages about 25 feet. A 6-foot-deep hole at Station 8+00 on Seismic Line 2 intersected rock that was classified as felsite. The high intercept of felsite along with relatively thin sections of vitrophyre and breccia at Borings 2.7, 2.10, and 2.12 suggests that the layer of glassy rocks is particularly thin just northwest of surface ground zero.

Compressional wave velocities in vitrophyre apparently range from about 4,000 to 8,000 ft/sec (Figure 2.4).

4.2.2 Felsite. Typical felsite is composed of 10 to 20 percent euhedral to subhedral oligoclase phenocrysts in a

cryptocrystalline groundmass (Appendix D). The color varies from brown to green but is mostly gray. A few vesicles concentrated in flow layers can be distinguished, especially near the change to overlying vitrophyre. Massive felsite has a bulk dry specific gravity of about 2.37 to 2.40. Most holes bottomed in felsite.

According to the seismic velocity profiles shown in Figure 2.4 the felsite appears to have a compressive wave velocity of 8,000 to more than 12,500 ft/sec.

4.2.3 Vitrophyre Breccia. Although its mineralogical composition is essentially the same as that of vitrophyre, the vitrophyre breccia is physically a distinct rock type. It is composed of fragments of vitrophyre varying from sand to block size. The rock has higher porosity than the other rock at the site, as evidenced by lower bulk dry specific gravity (2.20), but partial welding and cementation by secondary minerals restore a measure of competence. Much of the rock seen in outcrops is composed of blocks of vitrophyre several feet across with intervening red granular zones. This material appears to be a transition to homogeneous vitrophyre.

Typical breccia from the cores consists of about 50 percent of fragments more than 1 inch across of black vitrophyre in a pink matrix of glass shards that are mostly less than 1/4 inch across.

The prominent layer of low-velocity material (2,700 to 3,000 ft/sec) extending across the site (Figure 2.4) at about a 50-foot

depth is most likely composed of vitrophyre breccia, possibly interlayered with vitrophyre.

4.2.4 Intermediate Rocks. Transitional rock types are recognized between vitrophyre and felsite and between vitrophyre and vitrophyre breccia on the basis of field observations and stratigraphic position.

4.2.4.1 Lithoidal Vitrophyre and Glassy Felsite. Two intermediate rocks distinguished in the core logs (Appendix A) are lithoidal vitrophyre and glassy felsite. The petrographic examination of a sample of lithoidal vitrophyre from Hole 2.1 reveals characteristics of both the vitrophyre and felsite (Appendix D). The distinction between lithoidal vitrophyre and glassy felsite is subtle. Both types resemble the felsite but are more glassy. The bulk dry specific gravity of 2.38 of a sample of lithoidal vitrophyre is quite close to the specific gravities of felsite and vitrophyre.

4.2.4.2 Vesicular Vitrophyre. This subtype differs from the vitrophyre described above by the presence of 15 percent or more of vesicles and by its distinctly different physical properties. The bulk dry specific gravity of a sample is 2.08.

4.3 STRUCTURAL GEOLOGY

Planar and linear flow structures are evident in all rocks. Fractures with orientations geometrically related to the planar

flow structure are exceedingly abundant, particularly in the felsite.

4.3.1 Flow Structures. Primary flow structures in the form of continuous flow layers and flattened and lineated vesicles are developed extensively, particularly in the lithoidal vitrophyre and glassy felsite. Layers of massive vitrophyre commonly alternate with layers of less glassy types or with vesicular layers. In felsite, the flow structure may be manifested as parallel lenticular crystalline patches dispersed in a finer grained groundmass. The logs of borings presented in Appendix A reveal that flow layers dipped at angles greater than 45 degrees in most of the vitrophyre, lithoidal vitrophyre, and glassy felsite. This layering is represented schematically in cross sections in Figure 4.5. The layers, followed downward into the felsite, flattened gradually and became quite faint. Steep flow layers are characteristic of the tops of most rhyolitic lavas elsewhere.

Three of the several masses of vitrophyre outcropping near the site exhibited flow layers, and others had questionable structure. These appeared to have a preferred strike to the north or northeast. This structure was subsequently verified by data obtained in mapping the walls of the emplacement calyx hole (Appendix B). In the interval between 28 to 35 feet a prominent layer of vitrophyre in felsite strikes N35E and dips about 75SE. Such

flow structure imparts an anisotropy to the site media.

4.3.2 Joints and Fracturing. The felsite and related variants were highly jointed. Segments of core over 6 inches long were rare, and many of these were crossed by a few incipient joints. Ends of core that appeared at first to be drill breaks usually were found on close inspection to be joints along which there had been little or no separation. The vitrophyre and vitrophyre breccia are finely divided by incipient perlitic fractures.

Red coloration along many joints is probably due to oxidation of iron during the cooling of the lava. Locally highly fractured pockets or zones were observed in the felsite. Two such pockets, each several feet in diameter, were present in the access calyx hole (Appendix B) and emplacement cavity. Very highly fractured rocks generally provided poor core recovery. Cores recovered from these zones tended to be very weak in spite of an appearance of competence. For example, cores from 188 feet in Hole 2.12 and 30 feet in Hole 2.7 can be broken to 1/2-inch or smaller fragments along incipient fractures by light taps of a prospector's pick.

Where a flow structure was evident, it was seen to have influenced the fracture pattern. Usually a single, well-developed set of joints dominating in any domain tended to be oriented parallel or perpendicular to the planar flow structure. Spacing of incipient fractures in the felsite was commonly about 2 inches, and

platy fragments typify nearby outcrops. The perlitic incipient fractures in vitrophyre isolated grains about 1/8 inch in diameter.

4.3.3 Major Fracture Zones. Some major fracturing with possible shear offset was suspected in the zone of brecciated felsite encountered between 82 and 102 feet in Hole 2.12. The open spaces within this breccia had been partially lined with fine-grained calcite, and the breccia had the appearance of a veinlike tabular mass that dips about 80 degrees. A vein width of 3 feet was inferred from the interval along the obliquely intersecting drill hole.

A second breccia zone, not recognized in the limited amount of core, was detected in photographs at 75 through 85 feet in Hole 2.1. Here a white matrix, probably of calcite, constituted about 50 percent of the rock volume. At the present time, it seems best to regard these brecciated zones as two of many that cut the site media rather than to regard them as two intercepts of the same brecciated zone.

The major fracture mapped in the calyx hole (Appendix B) between 24 and 42 feet had a strike of N55W and dip of 70N. It was thus a cross joint oriented about normal to the steep flow layering.

4.4 GROUNDWATER

In exploratory borings Bruneau 1 and 2, which were drilled for the planned Schooner event, water was encountered at about a 1,000-foot depth. In Bruneau 2, the water is confined to a fractured portion of the Idavada felsite by overlying massive felsite; when this felsite was penetrated, the water rose in the drill hole to about 885 feet below ground surface. The piezometric surface, on the basis of these two holes and elevations on the West Fork Bruneau River, is inclined north-northwest at about 25 feet per mile; when projected, it should lie at about 3,580 feet mean sea level, i.e. deeper than 1,000 feet at the Pre-Schooner II site.

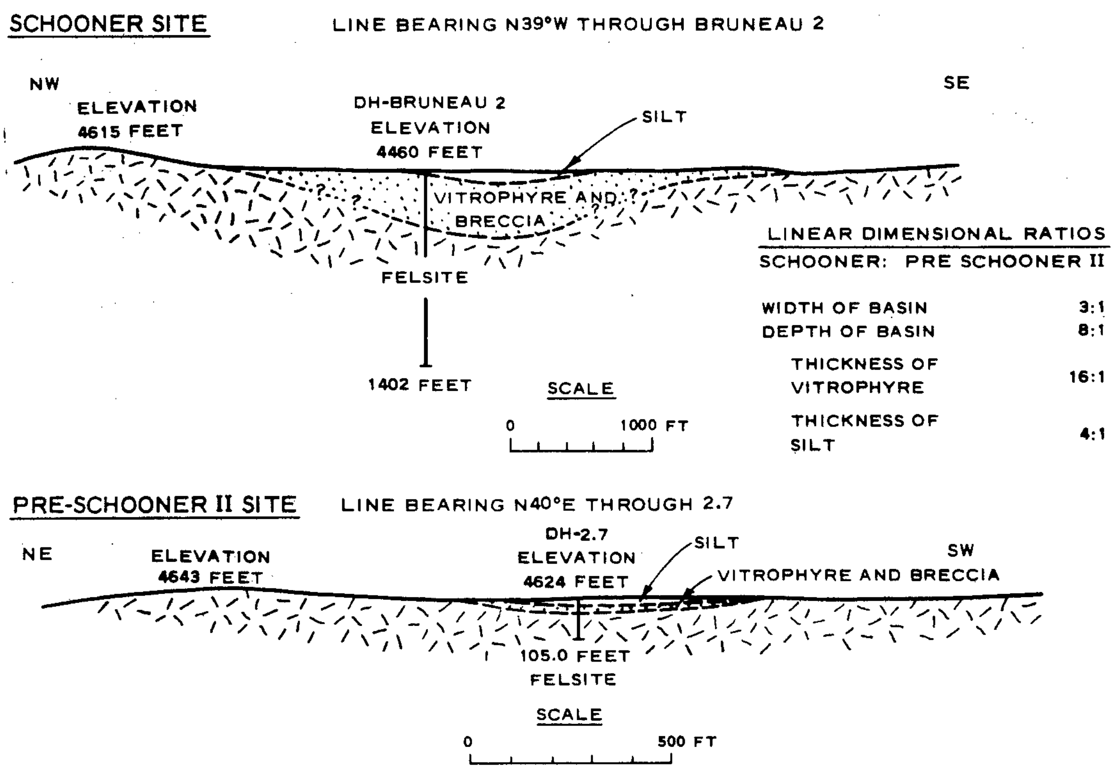


Figure 4.1 Comparison of inferred geological cross sections of Pre-Schooner II and Schooner sites.

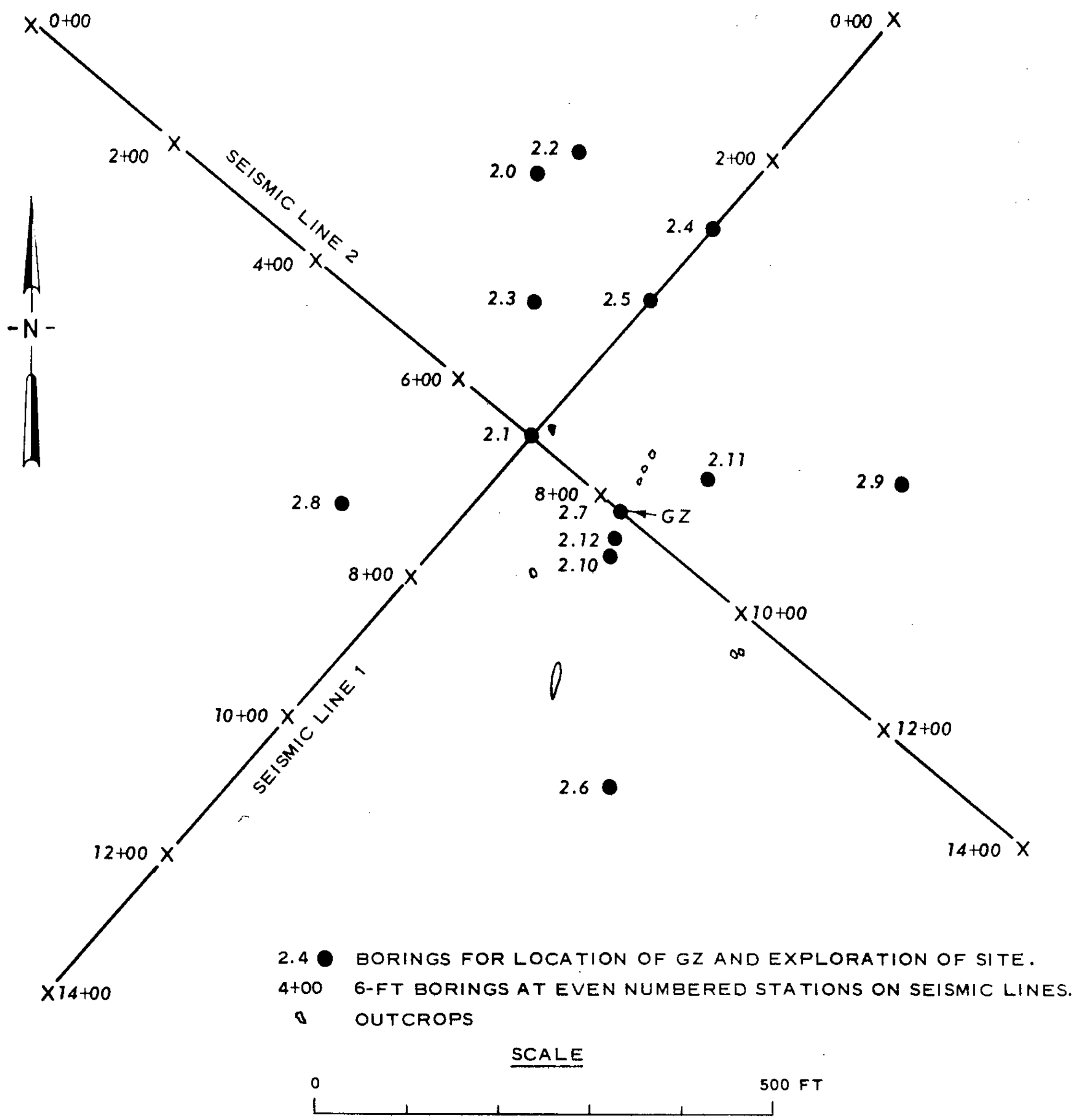


Figure 4.2 Location of borings and seismic lines at Pre-Schooner II site (Area 2).

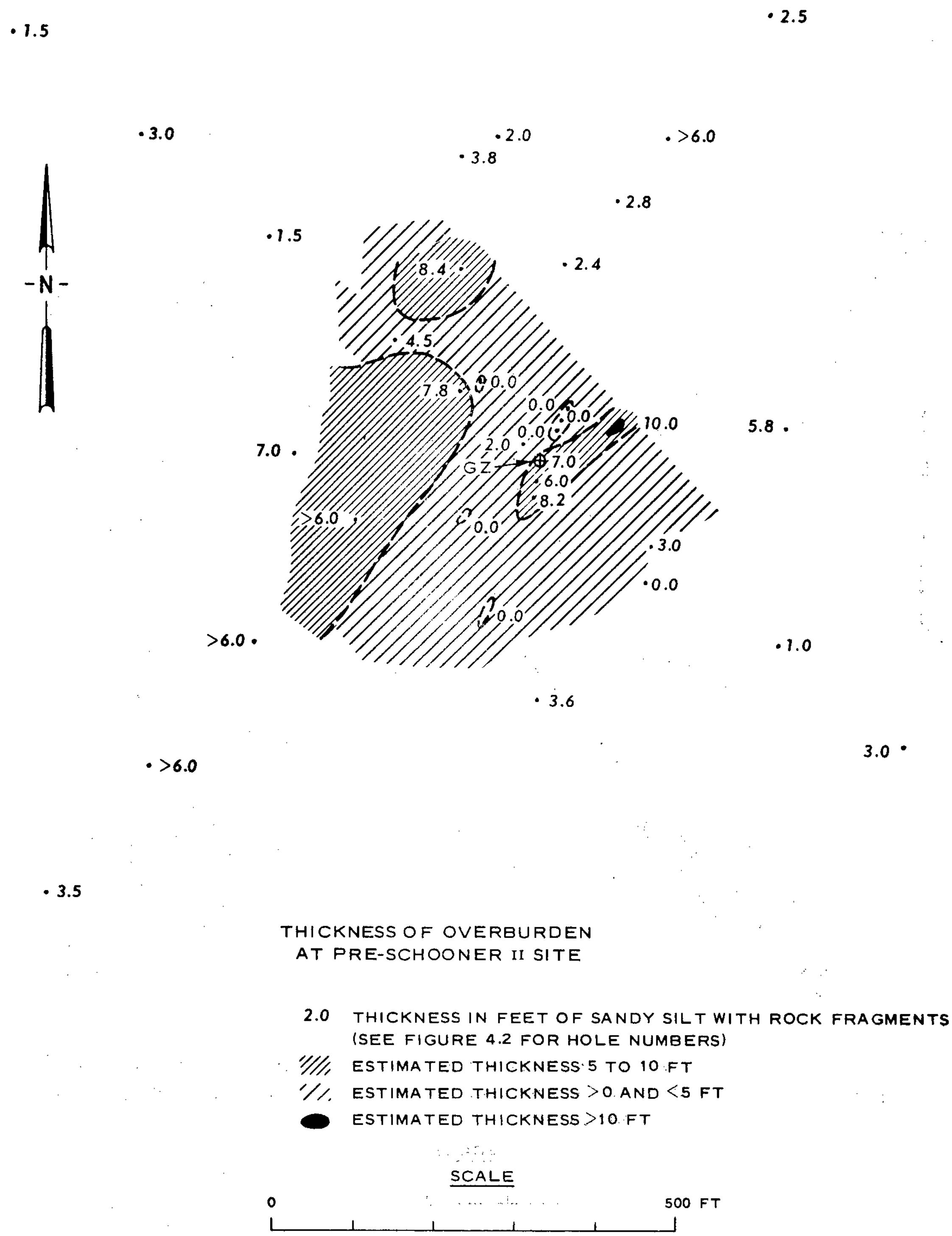


Figure 4.3 Thickness of overburden at Pre-Schooner II site.

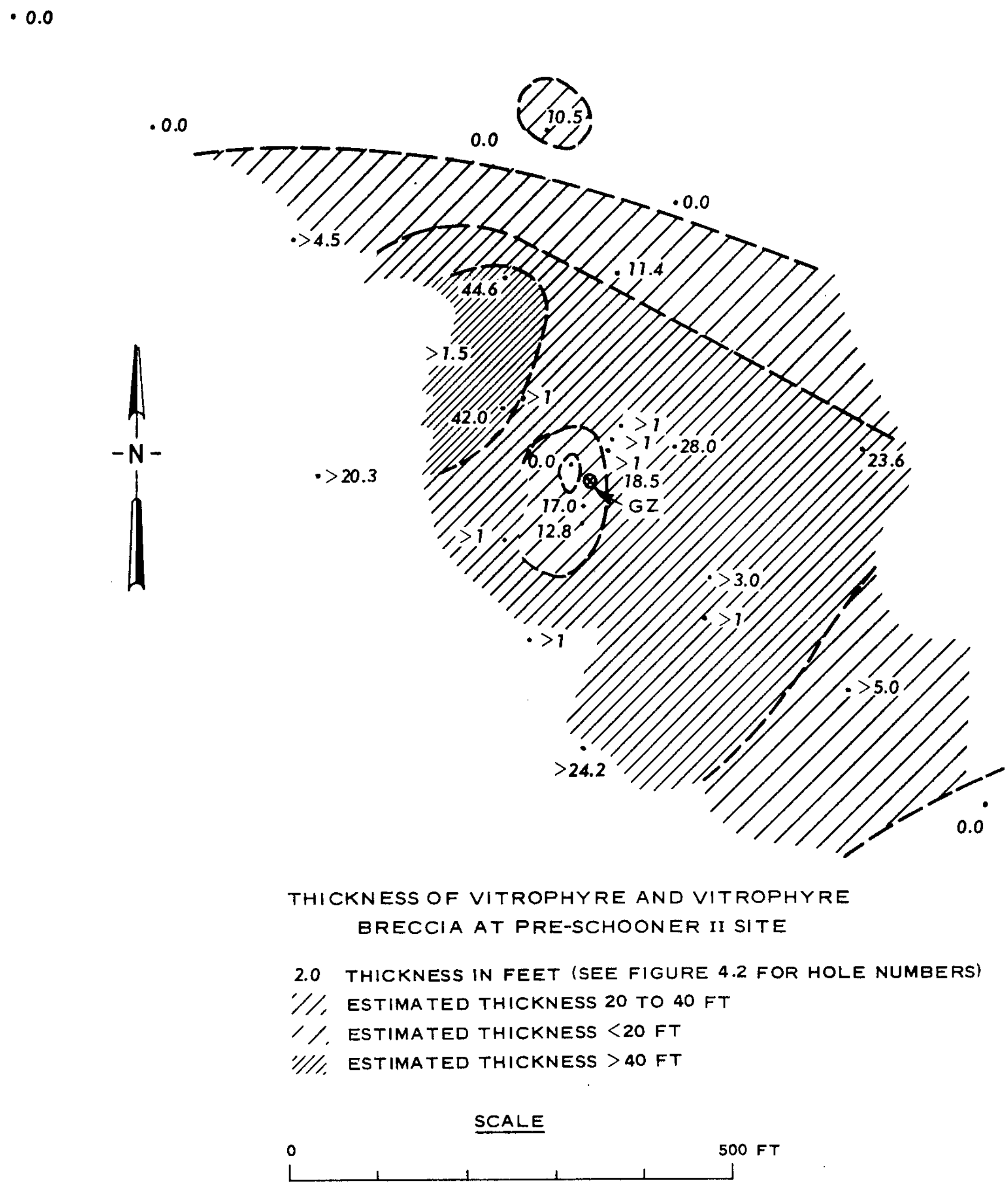


Figure 4.4 Thickness of vitrophyre and vitrophyre breccia at Pre-Schooner II site.

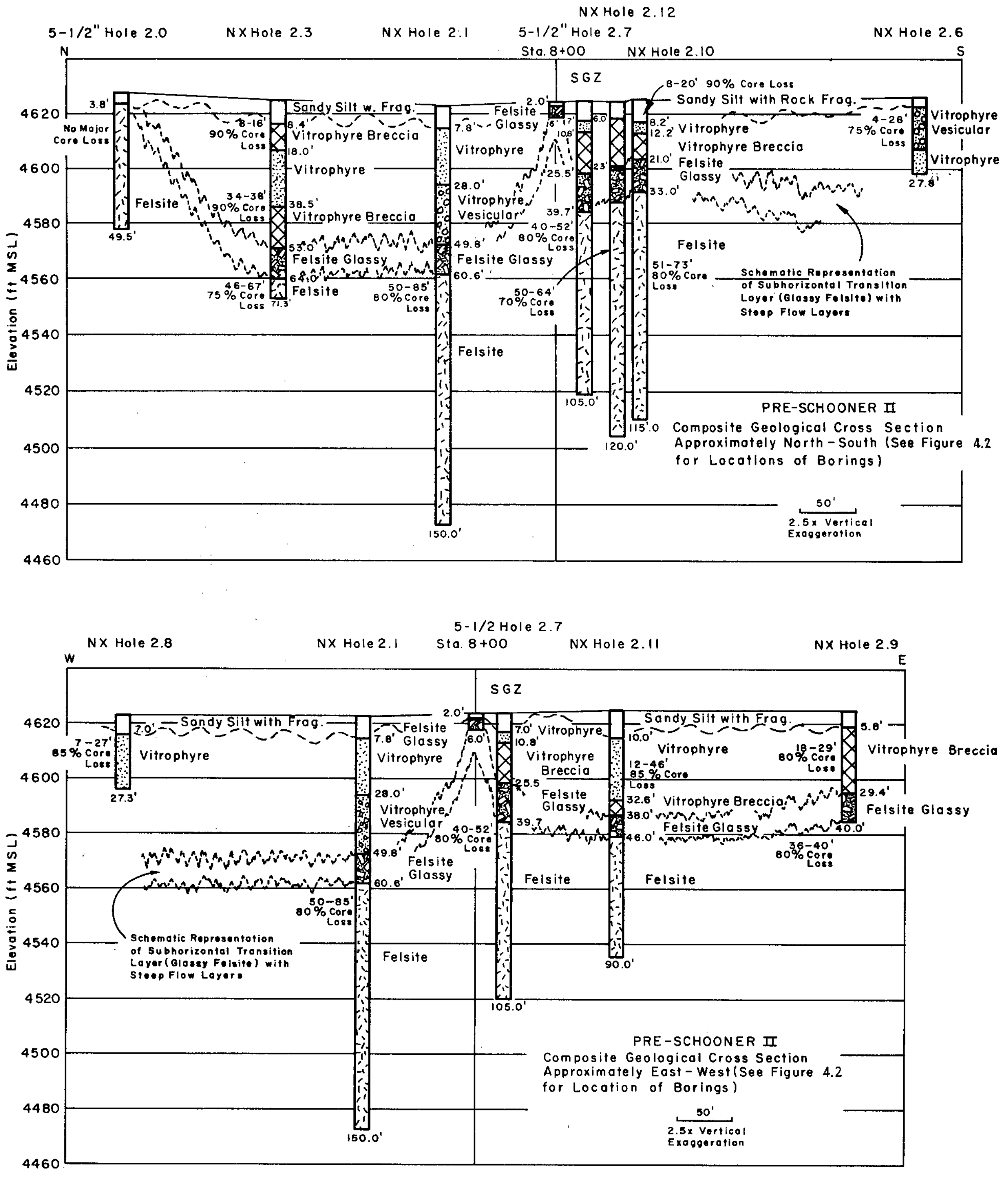


Figure 4.5 Detailed geological cross sections at Pre-Schooner II site.

CHAPTER 5

PHYSICAL PROPERTIES OF BEDROCK AT PRE-SCHOONER II SITE

Thirteen core samples from borings at the Pre-Schooner II site (Area 2) were subjected to detailed examination and physical testing. Representative samples from each of the major types of rock encountered were examined petrographically; Appendix D gives the results of the petrographic examination in detail. A sketch and a description of each core sample tested are presented in Appendix C.

5.1 SAMPLE DESCRIPTION

The laboratory examinations indicated that the mineralogical composition of the bedrock at the Pre-Schooner II site is generally the same at all depths, being primarily megascopic oligoclase and a few small corroded quartz and ferroan mineral phenocrysts in a rhyolitic, glassy to cryptocrystalline groundmass.

The detailed laboratory examination of the 13 core samples disclosed that all contained feldspar phenocrysts with maximum dimensions of approximately 1/64 to 3/8 inch. This examination also indicated that these samples could be initially divided into three general groups of bedrock, those representative of felsite, vitrophyre breccia, and vitrophyre.

The 13 core samples included all varieties of bedrock encountered at the site as follows: two samples of massive vitrophyre,

one sample of lithoidal vitrophyre, one sample of vesicular vitrophyre, two samples of layered vitrophyre, two samples of vitrophyre breccia, one sample of glassy felsite, three samples of layered felsite, and two samples of massive felsite.

5.2 PHYSICAL TESTS

The following physical properties were determined for 12 of the 13 samples tested in the laboratory: bulk specific gravity (G_m) under saturated, surface dry (SSD) conditions; bulk dry specific gravity (G_o) and corresponding density; specific gravity of solids (G_s) and corresponding density; porosity; static unconfined compressive strength; modulus of elasticity; and Poisson's ratio. The formulas used for determining the specific gravity are presented in detail in Appendix C. The results of the physical tests are given in Table 5.1.

5.2.1 Specific Gravity. The results of the specific gravity determinations and the corresponding density values are shown in Table 5.1. Density values were obtained by multiplying the respective bulk specific gravity values, SSD and dry, by the unit weight of water.

Surface openings were noted in the samples of vesicular vitrophyre and vitrophyre breccia (see sample descriptions, Appendix C). Since water was not retained in the larger of these surface voids,

the saturated, surface dry weight in air was slightly less than if all the voids were filled. Consequently, the bulk specific gravity (SSD) and corresponding density values shown in Table 5.1 are slightly higher than their true values.

Bulk specific gravities (SSD) (G_m) ranged from 2.46 to 2.36 for the felsites and from 2.45 to 2.15 for the vitrophyres. Corresponding densities ranged from 154 to 147 pcf for the felsites and 153 to 134 pcf for the vitrophyres.

The bulk dry specific gravities (G_o) were slightly lower than the bulk specific gravities (SSD). Ranges indicated in Table 5.1 and Figure 5.1 are 2.40 to 2.26 for the felsites and 2.40 to 2.08 for the vitrophyres. Corresponding densities ranged from 150 to 141 pcf for the felsites and from 150 to 130 pcf for the vitrophyres. The massive vitrophyres and massive felsites had the highest bulk dry specific gravities, which averaged about 2.40.

The specific gravity of solids (G_s) ranged from 2.56 for a massive felsite to 2.40 for vitrophyre breccia. The values of specific gravity of solids for the massive vitrophyres and massive felsites averaged 2.46 and 2.55, respectively. Values determined for lithoidal vitrophyre, glassy felsite, and layered felsite are between these averages, and values determined for vesicular vitrophyre and vitrophyre breccia are less. The values of specific gravity normally reported for vitrophyre and felsite

ranged from 2.65 to 2.40 (Reference 5).

5.2.2 Porosity. The porosity determined for each sample shown in Table 5.1 was calculated from the specific gravity of solids (G_s) and bulk dry specific gravity (G_o) according to the following formula:

$$\text{Porosity } (\%) = 100 \left(1 - \frac{G_o}{G_s} \right)$$

The porosity ranged from 14.4 percent for a vesicular vitrophyre to 1.6 percent for a massive vitrophyre (Figure 5.1). Average porosity values were 3.8 percent for the massive vitrophyre and 6.0 percent for the massive felsite. The porosity of all other varieties of vitrophyre and felsite was either equal to or higher than these averages.

5.2.3 Compressive Strength. The compressive strength for each of the 12 samples was determined by a static unconfined compression test. Procedures are described in Appendix C.

The results of static unconfined compression tests shown in Table 5.1 ranged from 21,940 to 5,970 psi for the varieties of felsites and from 9,010 to 3,090 psi for the varieties of vitrophyres. Plots of compressive strength with depth are shown in Figure 5.1 in relation to the predominant rock types. Too few tests were conducted to establish conclusively a relation between the specific gravity and unconfined compressive strength of the bedrock;

however, a relation between bulk dry specific gravity and unconfined compressive strength is suspected.

5.2.4 Modulus of Elasticity. Stress-strain curves for each of the 12 unconfined compression tests are given in Appendix C. A secant modulus of elasticity was obtained from each of the stress-strain curves by drawing a line through the origin to the approximate midpoint of the stress-strain curve, i.e. at a stress value of approximately one-half the ultimate sample strength. Values thus obtained are given in Table 5.1.

The modulus of elasticity values range from a maximum of 5.77×10^6 psi for massive vitrophyre to 0.84×10^6 psi for lithoidal vitrophyre (Figure 5.1). Respective maximum and minimum modulus of elasticity values for felsite are 4.94×10^6 psi (for a layered felsite) and 1.20×10^6 psi (for a glassy felsite). The massive felsites and massive vitrophyres average 4.64×10^6 and 4.4×10^6 psi, respectively. All other varieties of material have lower average modulus values.

5.2.5 Poisson's Ratio. The values of Poisson's ratio shown in Table 5.1 range between 0.25 and 0.10 for the vitrophyres and between 0.21 and 0.15 for the felsites. The averages of reliable Poisson's ratios for vitrophyre and felsite samples are 0.19 and 0.18, respectively.

5.3 GENERALIZED CONDITIONS

Two layers of bedrock are conspicuous at the Pre-Schooner II site on the basis of the physical properties. These layers correspond to the two distinguished in the field on the basis of megascopic characteristics, i.e. an upper layer of vitrophyre, vitrophyre breccia, and glassy felsite over a more crystalline felsite layer within which the explosives cavity was located. Variations of physical properties with depth are shown in Figure 5.1.

In Hole 2.7 (ground zero) the upper bedrock layer consisted of about 4 feet of vitrophyre, 15 feet of vitrophyre breccia, and 14 feet of glassy felsite, all underlying 7 feet of overburden.

5.3.1 Upper Bedrock. Eight samples were tested from the upper bedrock layer. These samples had the following average physical properties: bulk specific gravity (SSD), 2.34; bulk dry specific gravity, 2.28; specific gravity of solids, 2.46; porosity, 7.4 percent; unconfined compressive strength, 5,860 psi; modulus of elasticity, 2.60×10^6 psi; and Poisson's ratio, 0.20. Compressional wave velocities measured in the field (see Chapter 2) ranged from 2,000 to 8,000 ft/sec.

5.3.2 Lower Bedrock. The properties of the felsite of the lower bedrock contrast with those of the overlying layer. Five samples revealed the following average values: bulk specific gravity (SSD), 2.44; bulk dry specific gravity, 2.38; specific

gravity of solids, 2.54; porosity, 6.0 percent; unconfined compressive strength, 16,610 psi; modulus of elasticity, 4.1×10^6 psi; and Poisson's ratio, 0.18. Compressional wave velocities from seismic work were from 8,000 to more than 12,500 ft/sec (see Chapter 2).

TABLE 5.1 RESULTS OF PHYSICAL TESTS ON SAMPLES FROM PRE-SCHOONER II SITE

Boring Number	Sample Depth		Sample Description	Specific Gravity Determinations			Bulk Density		Porosity	Unconfined Compressive Strength	Modulus of Elasticity	Poisson's Ratio
	From	To		Bulk SSD	Bulk Dry G_o	Solids G_s	SSD	Dry				
	feet	feet					pcf	pcf	percent	psi	10^6 psi	
2.1[a]	17.7	18.5	Massive vitrophyre	2.43	2.40	2.44	152	150	1.6	7,320	3.13	0.18
2.1[a]	26.4	26.9	Lithoidal vitrophyre	2.45	2.38	2.50	153	149	4.8	3,820	0.84	0.71[b]
2.1	43.5	44.0	Vesicular vitrophyre	2.15	2.08	2.43	134	130	14.4	3,090	2.50	0.25
2.1	86.3	86.7	Layered felsite	2.41	2.37	2.54	150	148	6.7	19,710	4.94	0.19
2.1[a]	109.5	110.0	Layered felsite[c]	2.44	2.40	2.52	152	150	4.8	d	--	--
2.3[a]	43.4	44.0	Vitrophyre breccia	2.26	2.20	2.40	141	137	8.3	4,450	2.44	0.24
2.3	44.0	44.4	Vitrophyre breccia	2.28	2.21	2.43	142	138	9.1	6,410	2.46	0.16
2.6	19.4	20.0	Layered vitrophyre	2.40	2.35	2.49	150	147	5.6	6,830	2.47	0.10
2.8	8.1	8.7	Massive vitrophyre	2.39	2.34	2.49	149	146	6.0	9,010	5.77	0.24
2.10	26.4	27.4	Glassy felsite	2.36	2.26	2.49	147	141	9.2	5,970	1.20	0.21
2.10	31.5	32.2	Layered felsite	2.44	2.36	2.52	152	147	6.4	7,730	2.29	e
2.10	77.1	77.8	Massive felsite	2.45	2.39	2.56	153	149	6.6	21,940	4.68	0.20
2.10	108.3	109.3	Massive felsite	2.46	2.40	2.54	154	150	5.5	17,050	4.59	0.15

a Sample was examined petrographically.
b Doubtful results.
c Sample was classified as vitrophyre on basis of microscopic examination (see Appendix D).
d Specimen broke along healed fracture.
e Gage was not functioning.

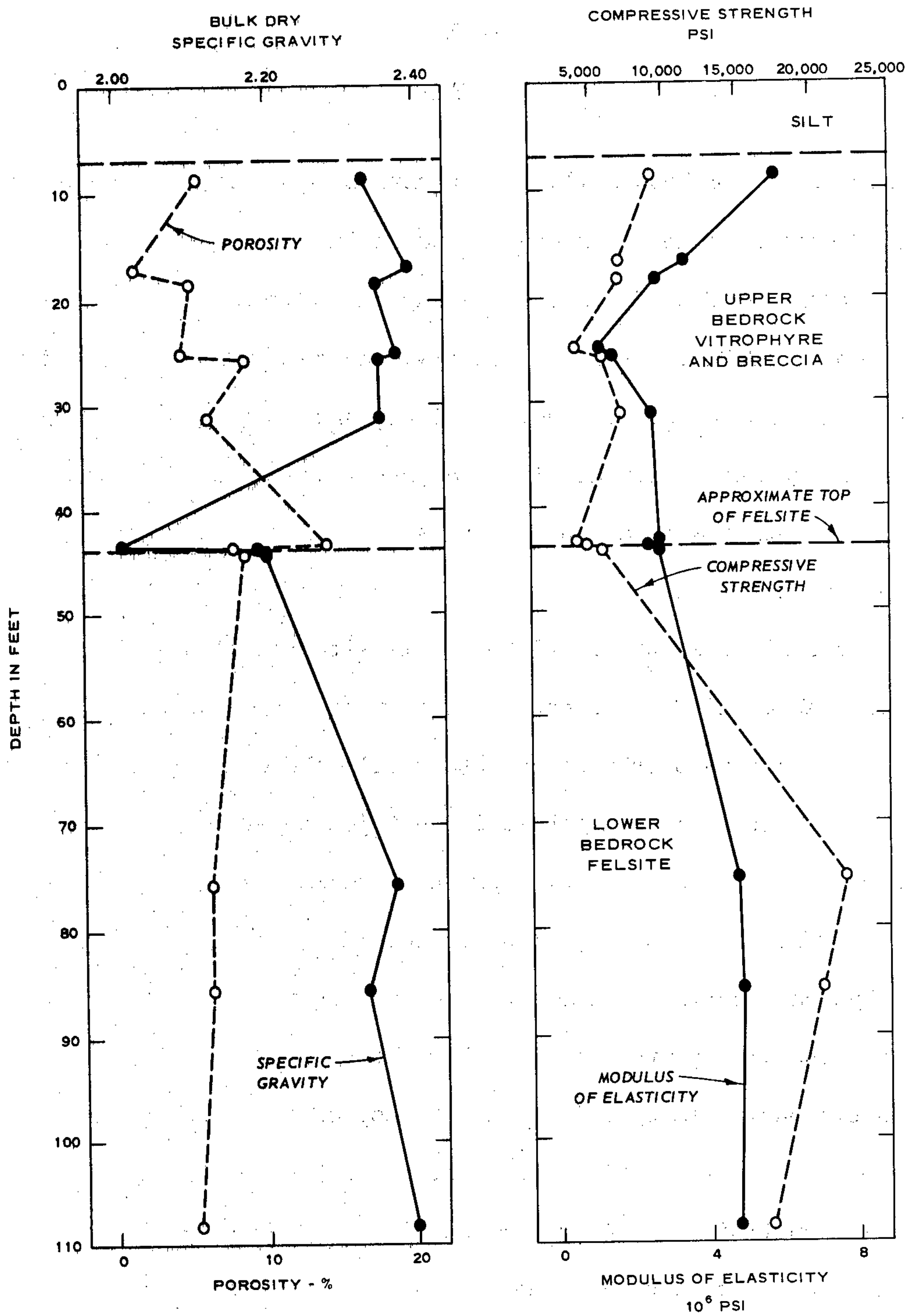


Figure 5.1 Physical properties of bedrock with depth at Pre-Schooner II site.

CHAPTER 6

SUMMARY

Project Pre-Schooner II, a high-explosive cratering experiment, was conducted in a new rock medium and is the next step in a continuing program of study of engineering characteristics of craters by the Corps of Engineers. The site was chosen with the help of refraction seismic surveys, core borings, and geological examinations. It geometrically models, reasonably well, the contrasting rock types anticipated at the nearby site for Project Schooner, a planned nuclear event.

Core borings at the Pre-Schooner II site revealed a blanket averaging about 25 feet thick of mixed vitrophyre and vitrophyre breccia between an overburden of stony silt above and felsite below. Gradational intermediate lithologic subtypes separate the three principal lithologic types of bedrock. Felsite is believed to continue well below the explored 150-foot depth.

Physical testing of samples bore out the twofold division of strata. The vitrophyre and vitrophyre breccia plus about 15 feet of conspicuously glassy felsite at the top of the felsite layer are typified by relatively high porosities, low compressive strengths, and low moduli of elasticity compared to the deeper felsite.

The selected site was found to have two notable variances from simplest geometry. First, the thickness of the upper layer composed

of vitrophyre and vitrophyre breccia varied in a complicated manner, and one particularly thin area was located within 30 feet of surface ground zero. Second, the vitrophyre and the intermediate rock type, glassy felsite, have a flow layering that usually cuts obliquely across the units at a steep dip. The steep flow layers strike north to northeast. This planar element imparted to the upper media an anisotropy, which in turn influenced joints that formed subsequently. Joints tend to be parallel and perpendicular to flow layers. The frequency of natural fractures per foot encountered in the vertical holes for all rocks ranged from 1 to 10 for felsite to hundreds of incipient perlitic fractures for vitrophyre.

APPENDIX A

LOGS OF BORINGS DRILLED FOR PROJECT PRE-SCHOONER II

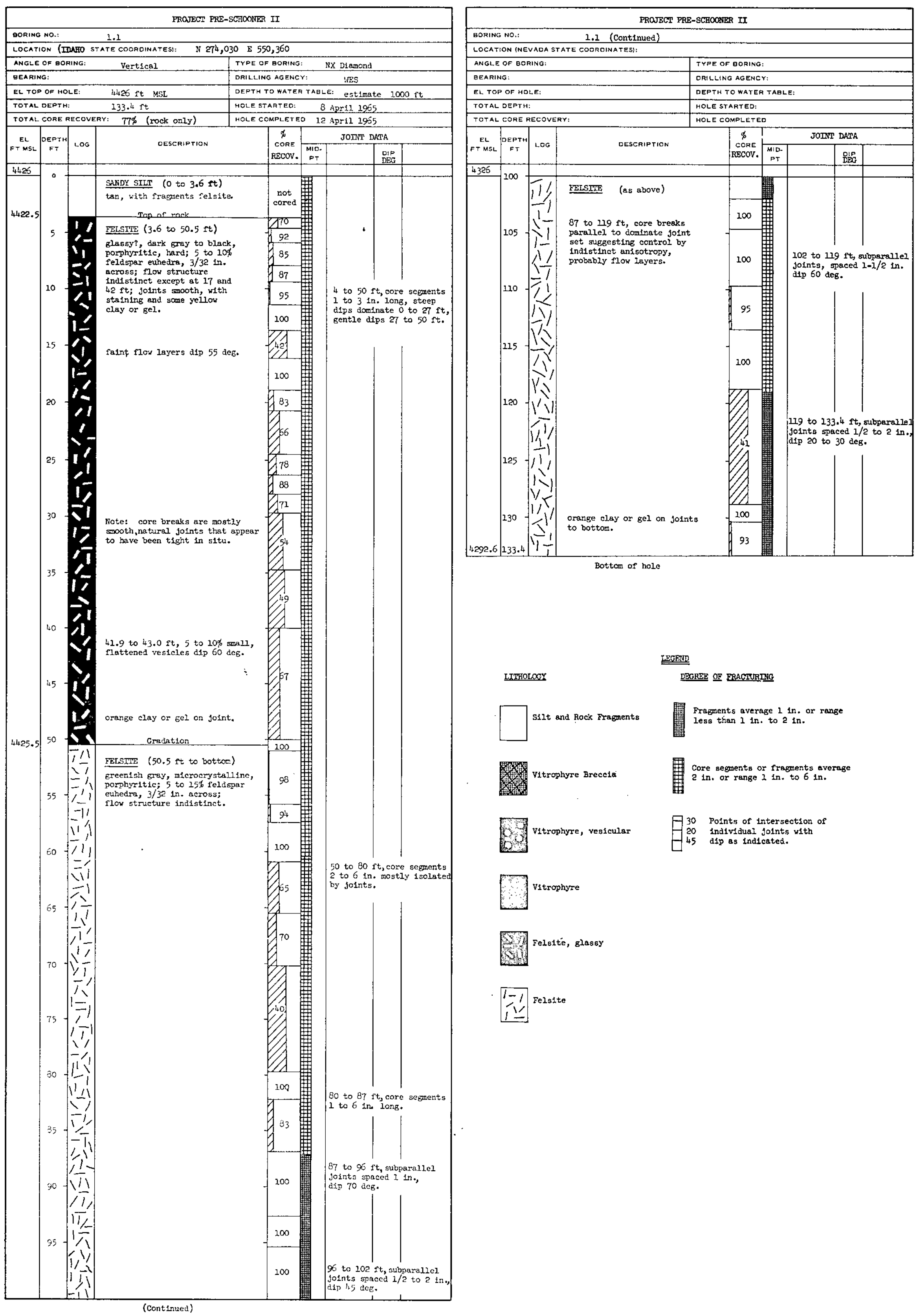


Figure A.1. Log of Core Boring 1.1.

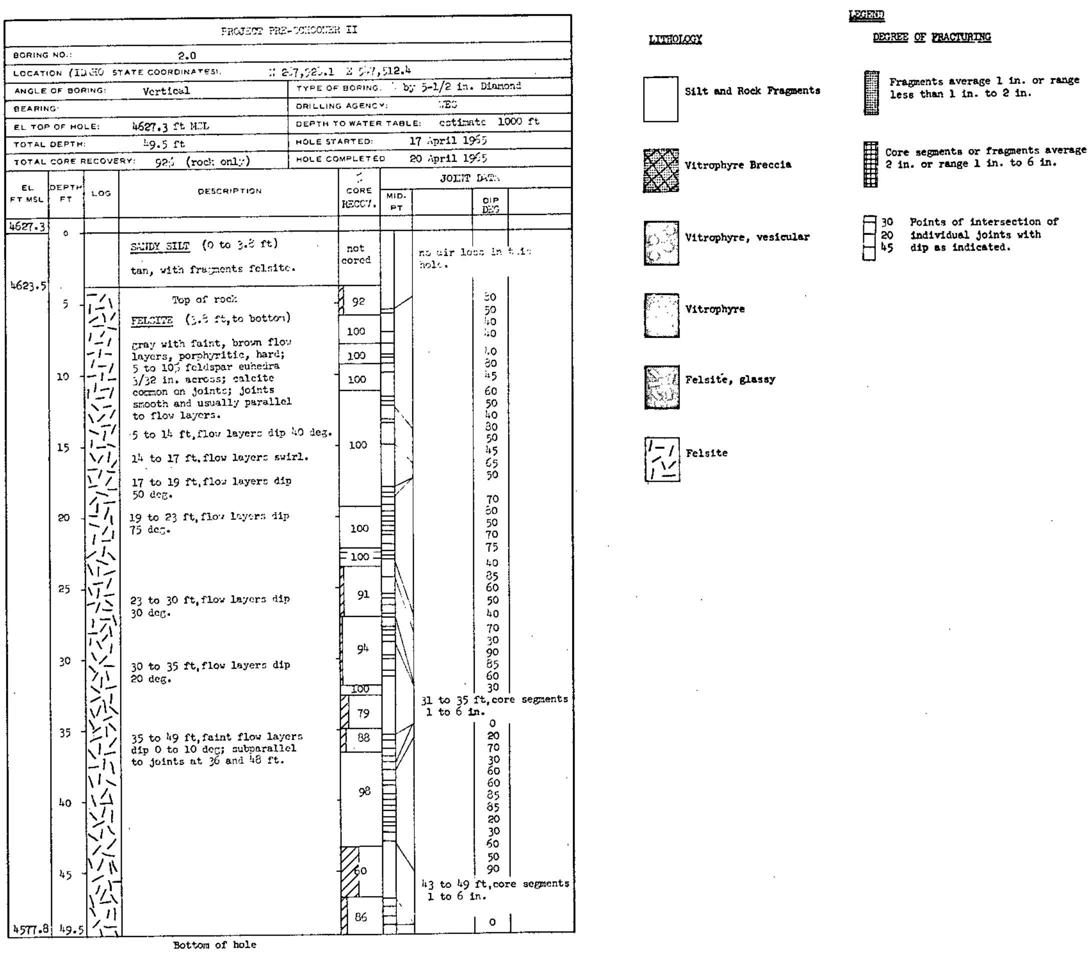


Figure A.2 Log of Core Boring 2.0.

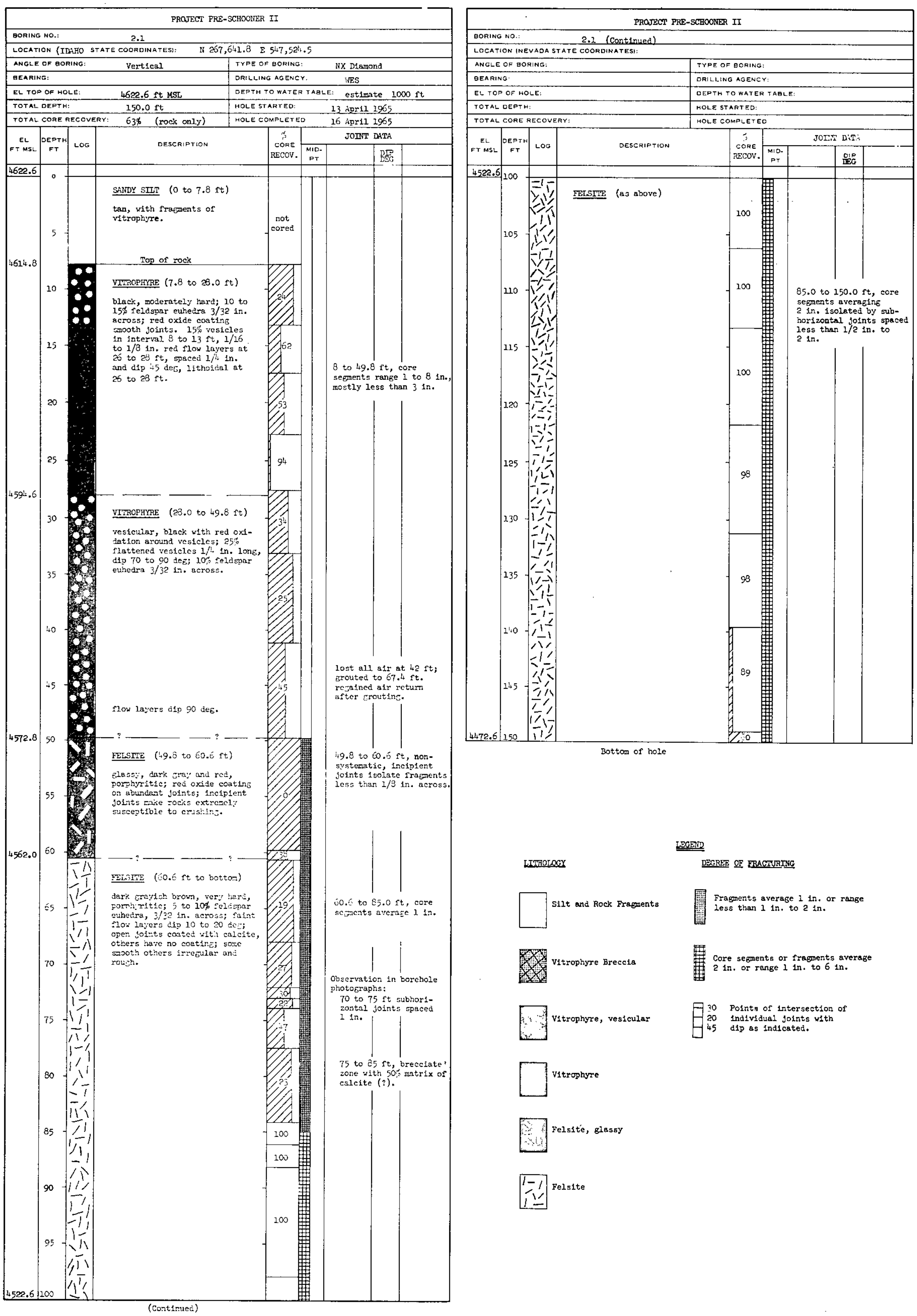


Figure A.3 Log of Core Boring 2.1.

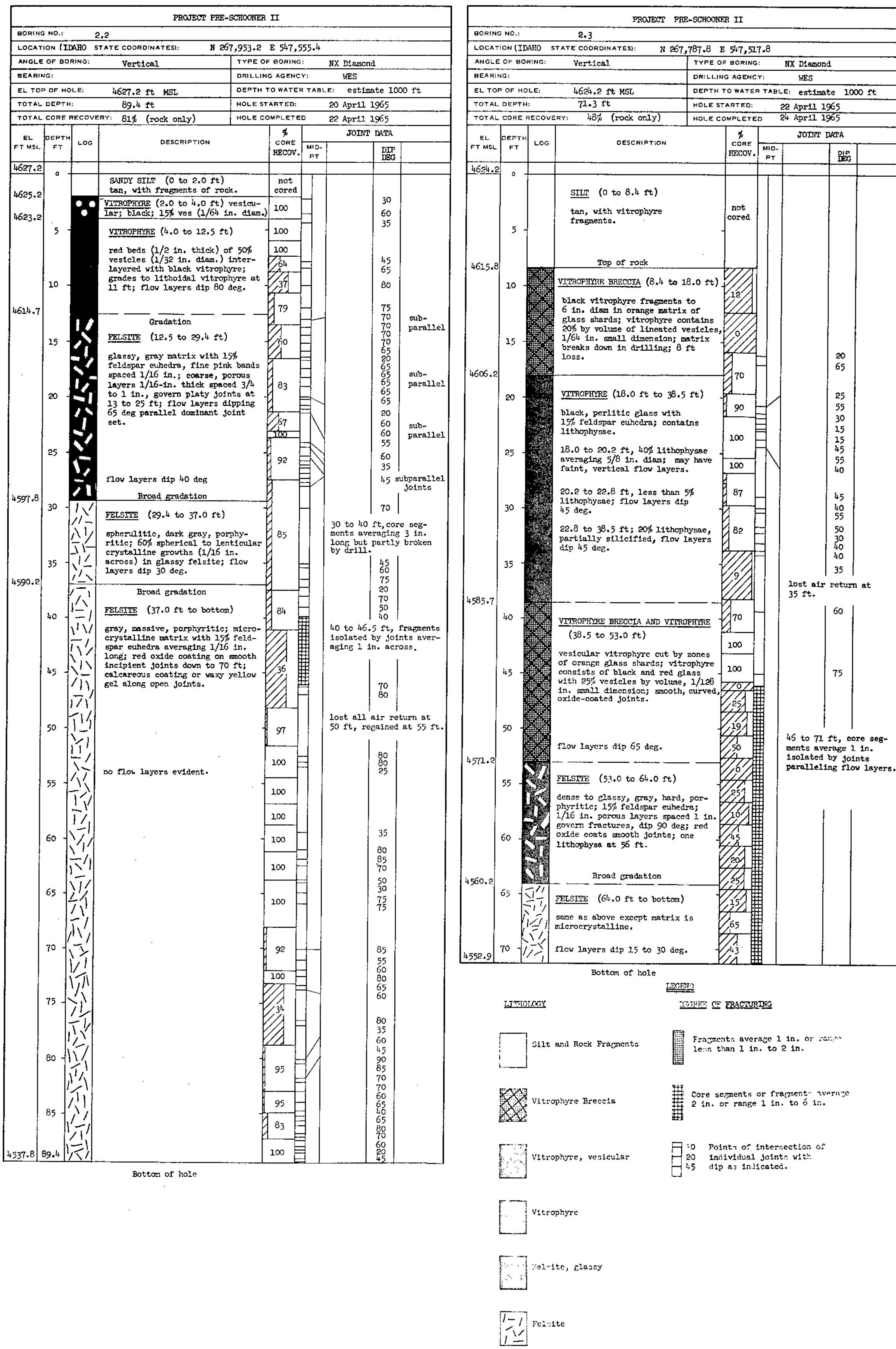


Figure A.4 Logs of Core Borings 2.2 and 2.3.

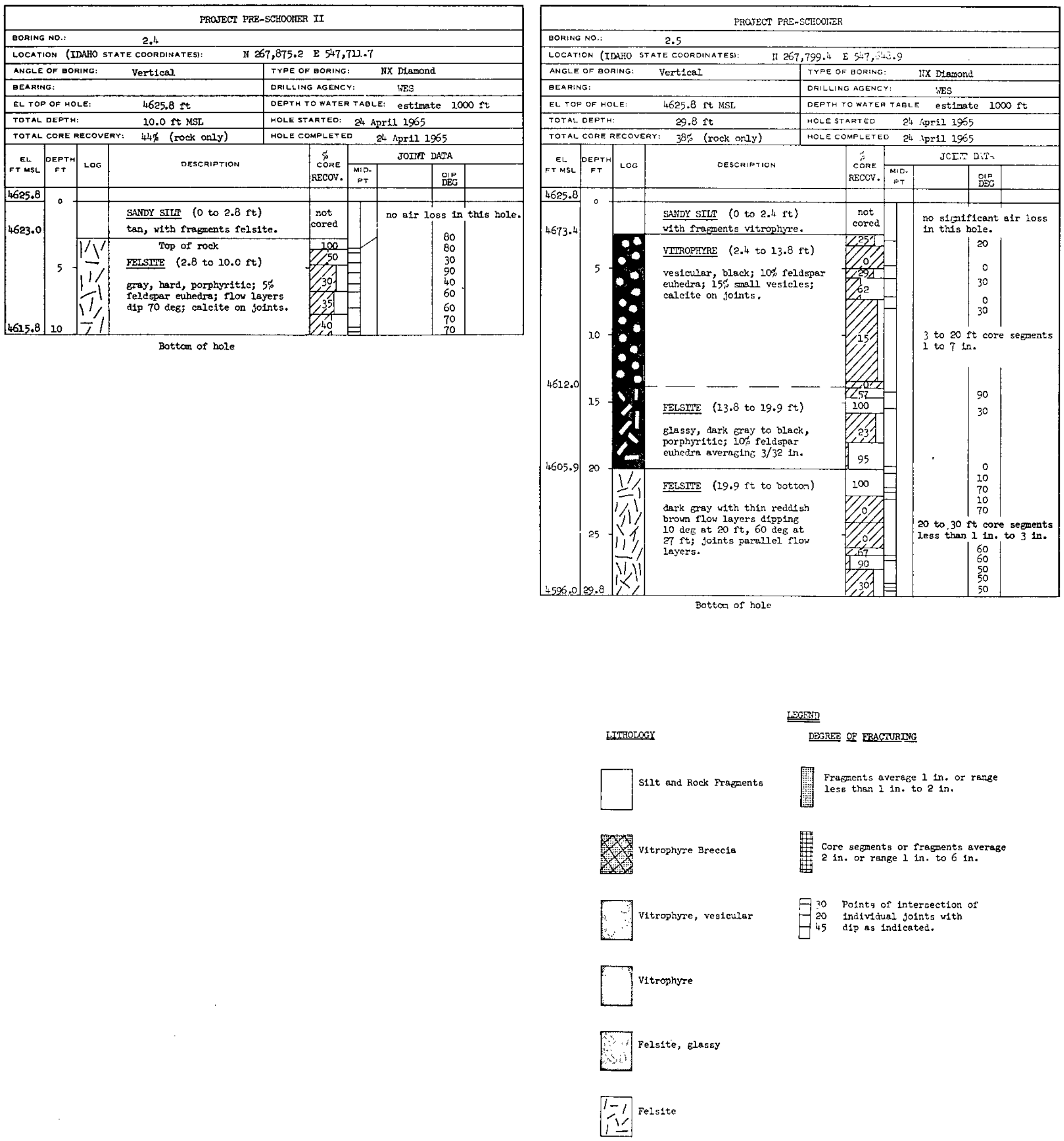


Figure A.5 Logs of Core Borings 2.4 and 2.5.

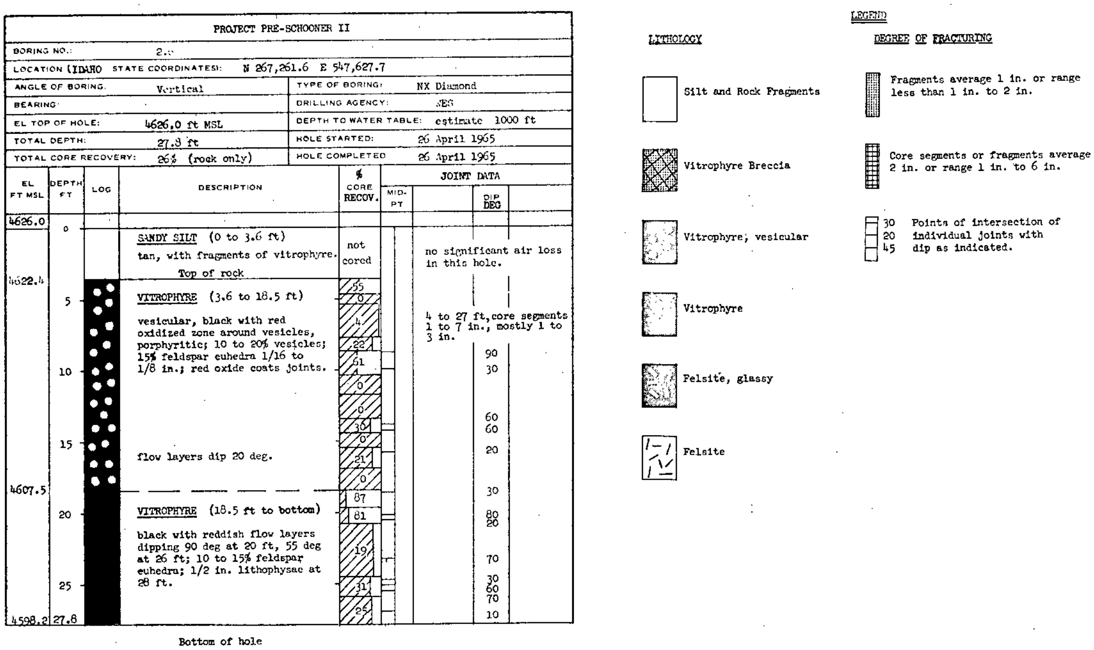


Figure A.6 Log of Core Boring 2.6.

PROJECT PRE-SCHOONER II

BORING NO.:	2.7 (SS2)		
LOCATION (IDAHO STATE COORDINATES):	N 267,551.6 E 547,626.6		
ANGLE OF BORING:	Vertical	TYPE OF BORING:	4 by 5-1/2 in. Diamond
BEARING:		DRILLING AGENCY:	EG
EL TOP OF HOLE:	4624.0 ft MSL	DEPTH TO WATER TABLE:	estimate 1000 ft
TOTAL DEPTH:	105.0 ft	HOLE STARTED:	26 April 1965
TOTAL CORE RECOVERY:	7-% (rock only)	HOLE COMPLETED:	4 May 1965

EL FT MSL	DEPTH FT	DESCRIPTION	% CORE RECOV.	JOINT DATA	DIP DEG
4624.0	0	SANDY SILT (0 to 7.0 ft) tan, with fragments of vitrophyre.	not cored	no significant air loss in this hole.	
4617.0	7.0	Top of rock VITROPHYRE (7.0 to 10.8 ft) lithoidal; gray to black, slightly vesicular; 10 to 15% feldspar euhedra; thin, orange flow layers at 10 ft dip 70 deg.	100, 53, 100, 75		60, 60, 60
4613.2	10.8	VITROPHYRE BRECCIA (10.8 to 25.5 ft) 50% vitrophyre fragments 6 in. minus in porous orange matrix of glass shards; vitrophyre is vesicular; veinlets of orange matrix extend 10 ft into glassy felsite below.	83, 89, 100	11 to 25 ft, core segments average 9 in. 8.6 to 20.6 ft, hole grouted.	
4598.5	25.5	FELSITE (25.5 to 39.7 ft) glassy; dark gray, dense flow layers alternating with brown, porous layers (to 1 in. thick) dipping 70 to 90 deg; 10% feldspar euhedra, 1/16 to 1/8 in. across; 10% voids in porous layers; steep 1 in. veinlets orange glass shards to 37 ft; rock breaks by taps of hammer to 1/8-in. chips locally.	61, 74, 65, 91, 100, 100	25 to 40 ft, core segments less than 1/2 in. to 6 in.	
4584.3	39.7	FELSITE (39.7 ft to bottom) gray to brown, porphyritic, microcrystalline matrix; hard; 10% feldspar euhedra, otherwise as above; calcite coating suggests minor voids. 40 to 56 ft, flow layers dip 80 to 90 deg, paralleled by dominant joint set. flow layers dip 30 deg. 63 to 85 ft, flow structure indistinct; joints are smooth, planar with 1/64-in. calcite closing space. faint flow layers dip 10 deg. 85 to 105 ft, variable joint orientations but one set persists dipping 10 to 30 deg.	15, 32, 0, 0, 58, 33, 67, 81, 21, 53, 100, 100, 100, 100, 86, 100, 100, 100, 100, 100, 79, 61, 92, 92, 100	40 to 56 ft, core segmented to less than 1/2 in. up to 1-1/2 in. on joints and flow layers. 44 to 52 ft, grouted after encountering 4 ft fall-in at 50 ft. 56 to 61 ft, core segments 1 to 2 in. 61 to 85 ft, core segments average 8 in. 85 to 105 ft, core segments 1 to 6 in.	65, 10, 60, 45, 40, 90, 10, 80, 85, 15, 60, 70, 10, 60, 30, 60, 50, 40, 80, 0, 60, 40, 60, 35, 10, 20, 80
4524.0	100				

(Continued)

PROJECT PRE-SCHOONER II

BORING NO.:	2.7 (Continued)		
LOCATION (IDAHO STATE COORDINATES):			
ANGLE OF BORING:		TYPE OF BORING:	
BEARING:		DRILLING AGENCY:	
EL TOP OF HOLE:		DEPTH TO WATER TABLE:	
TOTAL DEPTH:		HOLE STARTED:	
TOTAL CORE RECOVERY:		HOLE COMPLETED:	

EL FT MSL	DEPTH FT	DESCRIPTION	% CORE RECOV.	JOINT DATA	DIP DEG
4524.0	100	FELSITE (as above)	45		
4519.0	105				

Bottom of hole

LEGEND

LITHOLOGY

- Silt and Rock Fragments
- Vitrophyre Breccia
- Vitrophyre, vesicular
- Vitrophyre
- Felsite, glassy; and lithoidal vitrophyre
- Felsite

DEGREE OF FRACTURING

- Fragments average 1 in. or range less than 1 in. to 2 in.
- Core segments or fragments average 2 in. or range 1 in. to 6 in.
- 30, 20, 45 — Points of intersection of individual joints with dip as indicated.

Figure A.7 Log of Core Boring 2.7.

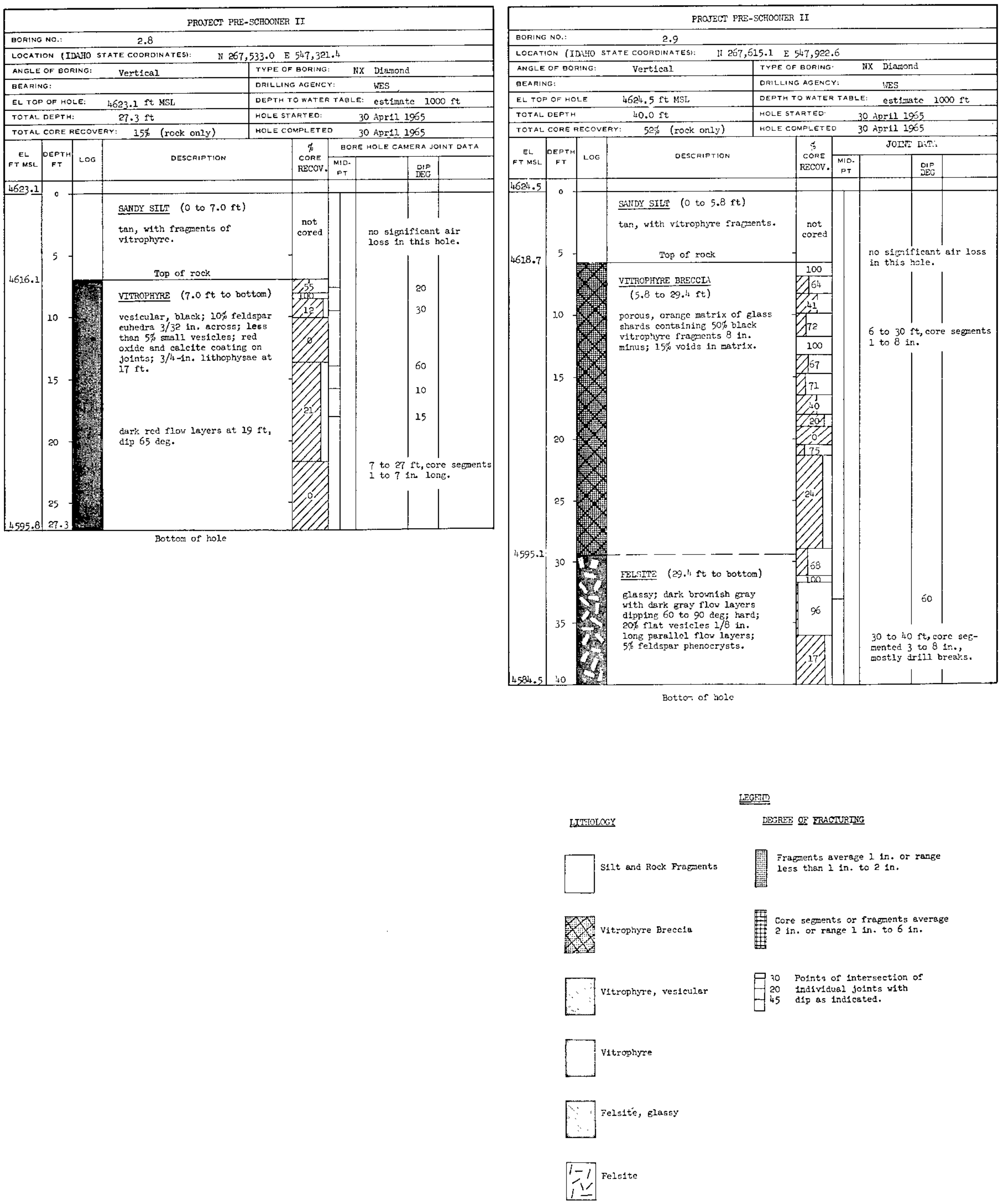


Figure A.8 Logs of Core Borings 2.8 and 2.9.

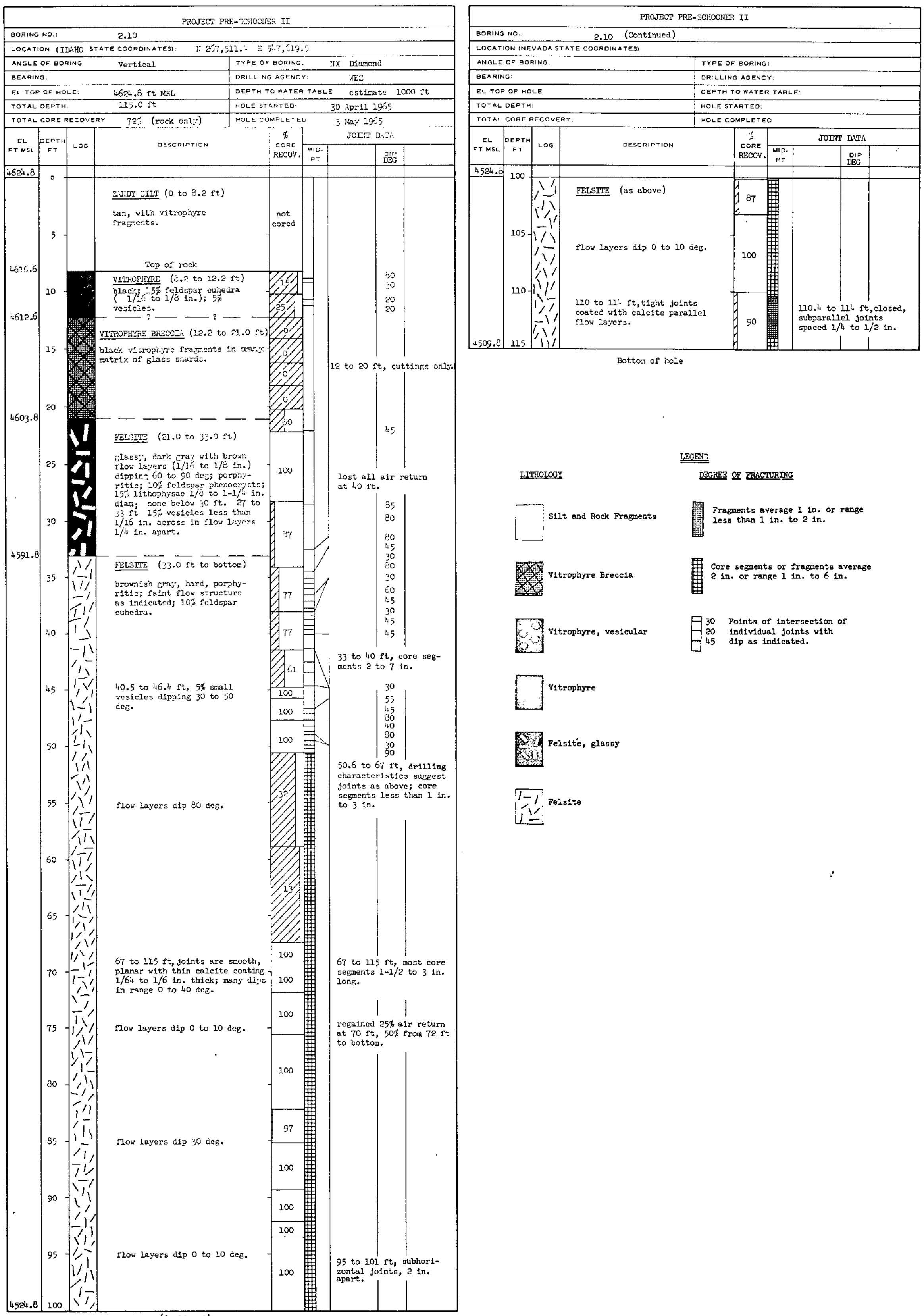


Figure A.9 Log of Core Boring 2.10.

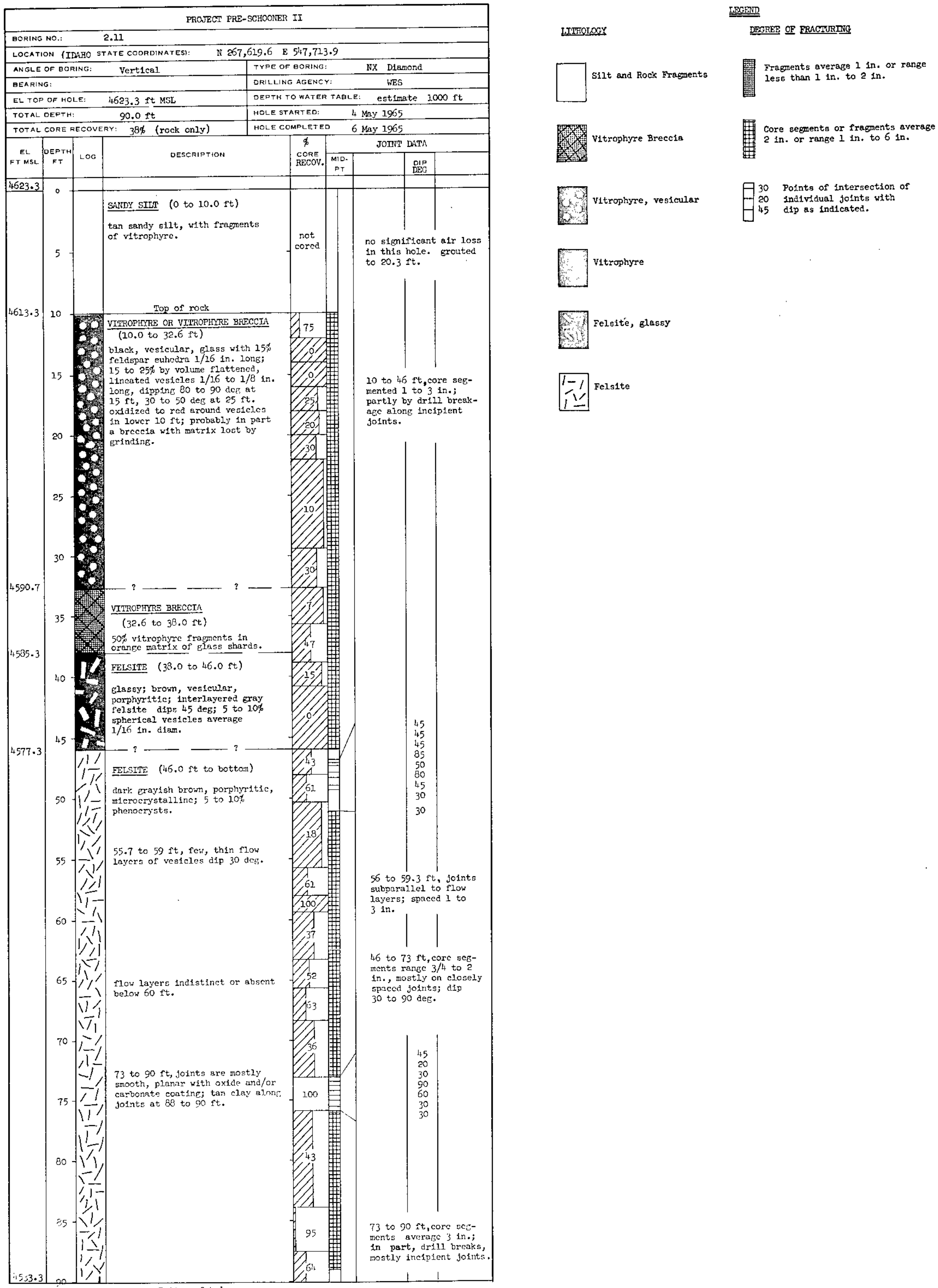


Figure A.10 Log of Core Boring 2.11.

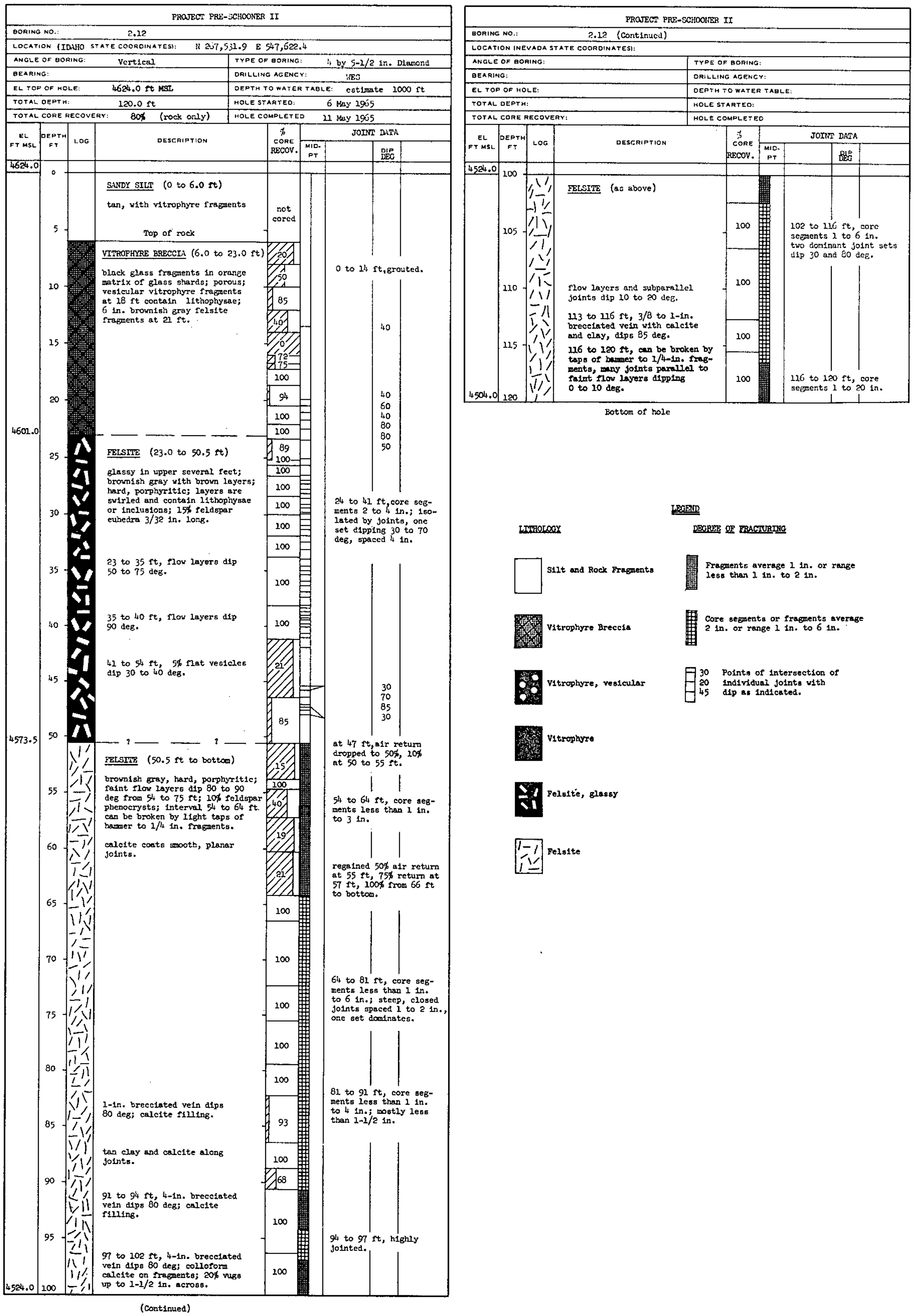


Figure A.11 Log of Core Boring 2.12.

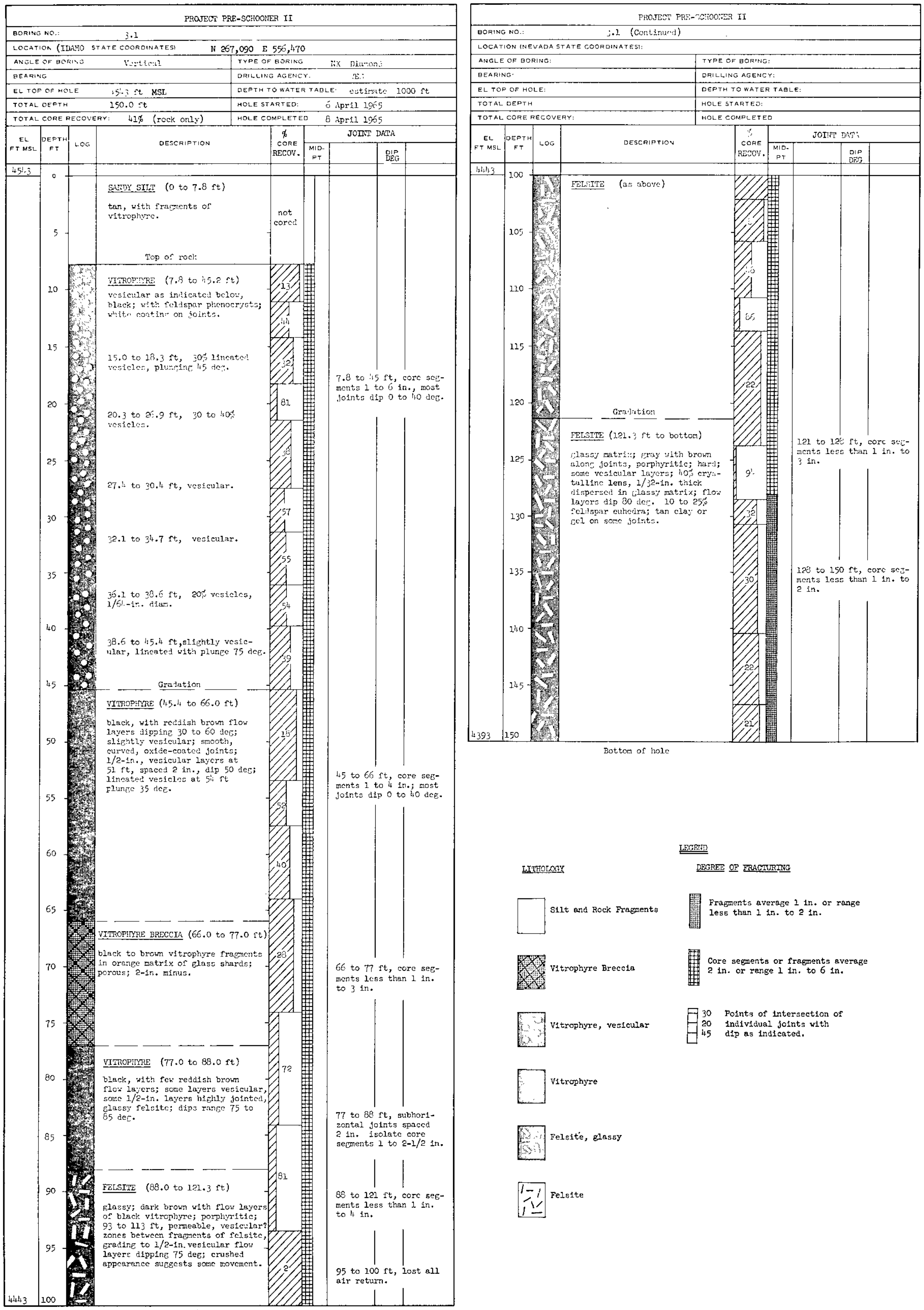


Figure A.12 Log of Core Boring 3.1.

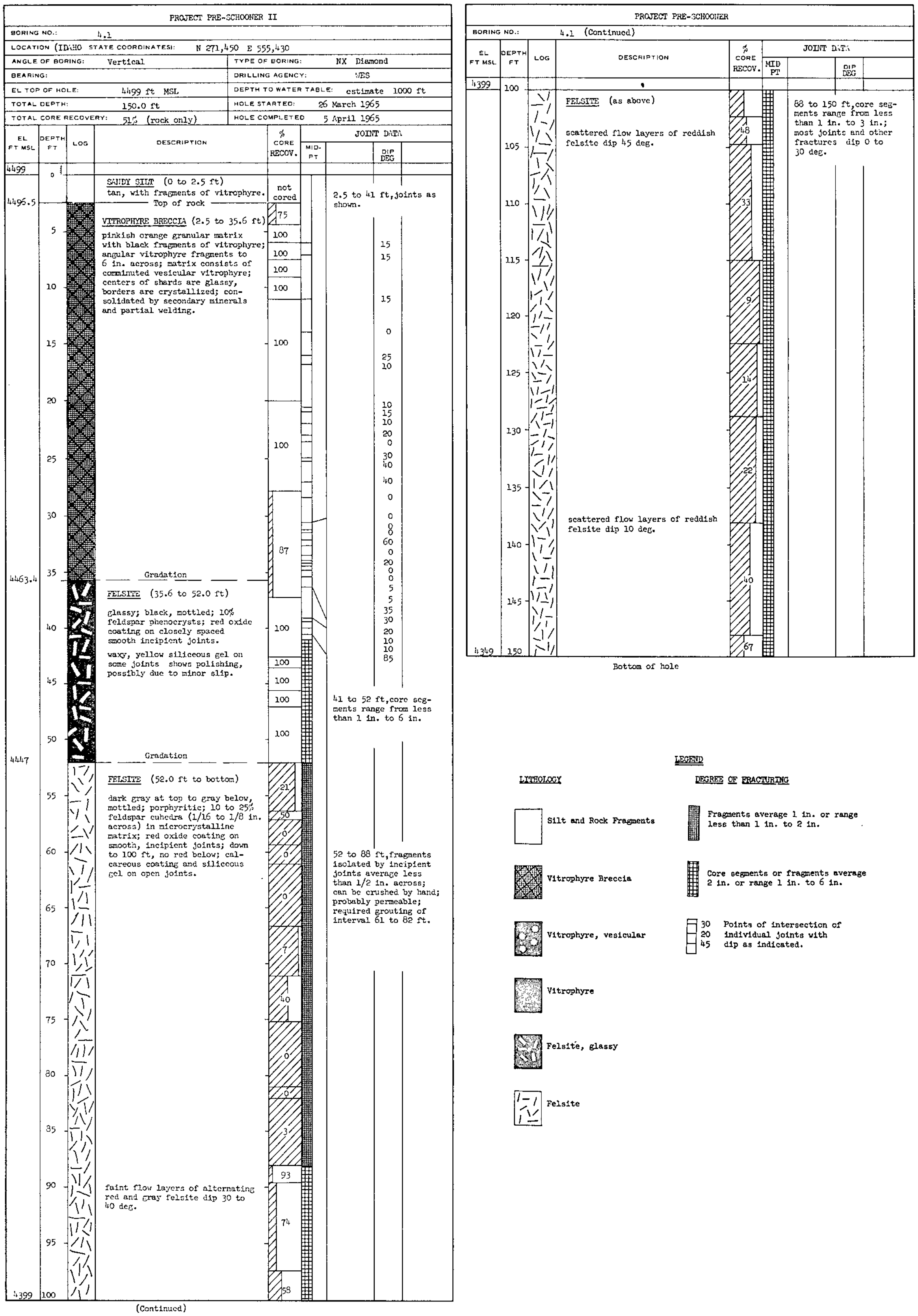


Figure A.13 Log of Core Boring 4.1.

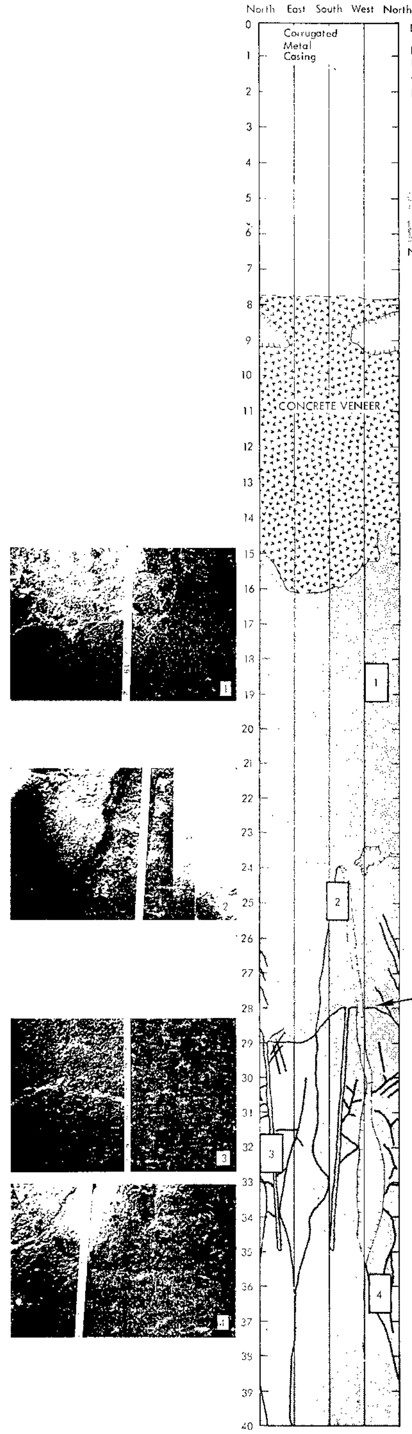
APPENDIX B

CALYX HOLE MAP

LOG OF ACCESS CALYX HOLE - PRE-SCHOONER II

Project: PRE-SCHOONER II
Hole No: Access shaft

Total depth: 61.2 ft
Hole dia.: 36 in.



Open joint or fracture

Tight joint or fracture

Cavity beyond general wall of hole

Vitrophyre Breccia

Felsite

Note: This log is schematic. Vertical exaggeration over the horizontal is approximately 2:1. Photo insets show the general character of the rock.

Bottom of casing

Hole in concrete coating exposing highly altered volcanic glass

Highly altered, crumbly, oxide stained, waxy glass matrix holding angular fragments of black volcanic glass or obsidian ranging from 0.02 to 0.8 ft maximum dimension.

Solid welded mass with few recognizable joints or fractures. Walls of the hole are pitted where the drilling process has eroded the softer matrix.

Exposed fragments of highly fractured felsite with maximum dimension 1 ft.

A prominent structural plane enters the hole from the SW. It is open to 2 in. with one smooth planar wall (N. side) and one wall of crushed rock. Plane migrates across the hole leaving through north wall at 41.7 ft.

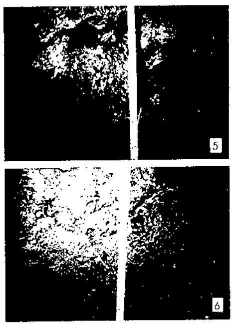
Approximate contact; gradational, changing from typical vitrophyre breccia of 26 ft to glassy felsite at 29 ft. Matrix of the breccia rapidly changes from small black obsidian fragments in altered glass matrix to uniform glassy to aphanitic, porphyritic, red-brown felsite.

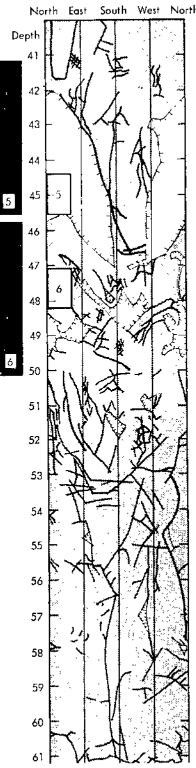
Near the top of the sequence the felsite is characterized by a hard, glassy matrix with subhedral to anhedral white and black phenocrysts. With depth, the matrix becomes more crystalline and darker in color. The phenocrysts become more euhedral.

The rock is permeated by small fracture planes similar to conchoidal fracturing in obsidian. Fairly good cohesion along these planes.

Joint on NE side of shaft open to 4 in. and filled with brecciated material.

LOG OF ACCESS CALYX HOLE (Continued)





Highly fractured as above but lacks cohesion along planes. Easily eroded. Walls of shaft eroded up to 3 in. deep. Fractures numerous, short, irregular (Not all fractures shown).

As above with waxy luster. Cohesion returned to small fracture planes. Walls eroded only along joints. Most cavities in wall from loss of wedge shaped fragments bounded by joint planes.

Most joints are short and curved.

T.D. = 61.2 ft.

APPENDIX C

PHYSICAL TESTS AND VISUAL EXAMINATION OF ROCK CORES FROM PRE-SCHOONER II SITE

APPENDIX C

PHYSICAL TESTS AND VISUAL EXAMINATION OF ROCK CORES FROM PRE-SCHOONER II SITE

C.1 DETERMINATIONS OF SPECIFIC GRAVITY

The following formulas were used to calculate specific gravities:

Bulk specific gravity (SSD) or G_m

$$G_m = \frac{W_s}{W_s - W_w}$$

Where: W_s = weight in air of the saturated, surface dry specimen

W_w = weight in water of the saturated specimen

Bulk dry specific gravity G_o

$$G_o = \frac{W_o}{V_o \gamma_w}$$

Where: W_o = weight of oven-dry specimen

V_o = measured volume of specimen

γ_w = density of water at temperature of test specimen

Specific gravity of solids G_s

$$G_s = \frac{W_{sa}}{W_{sa} - W_{sw}}$$

Where: W_{sa} = weight of dry crushed material in air

W_{sw} = weight of material in distilled water under a vacuum pressure

C.2 SAMPLE DESCRIPTION

The 13 NX core samples chosen for testing are illustrated and described in Figure C.1.

C.3 SAMPLE PREPARATION AND COMPRESSION TESTS

All samples were prepared in the following manner. The length-diameter ratio was approximately 2.0. The sawed ends of the cores of massive felsite were prepared by surface grinding. The ends of the remaining cores were prepared by capping sawed ends with hydrostone. The different manner of end preparation has very little effect on the strength of the sample, although experience has shown that when brittle rock with ends ground is tested for compressive strength, the strength values are slightly higher than when the ends are capped. A uniform loading rate of 50 psi/sec was applied to all specimens. Strain measurements were made by two pairs of diametrically opposed SR-4 strain gages bonded to the specimen. Stress-strain curves obtained from these tests are shown in Figure C.2.

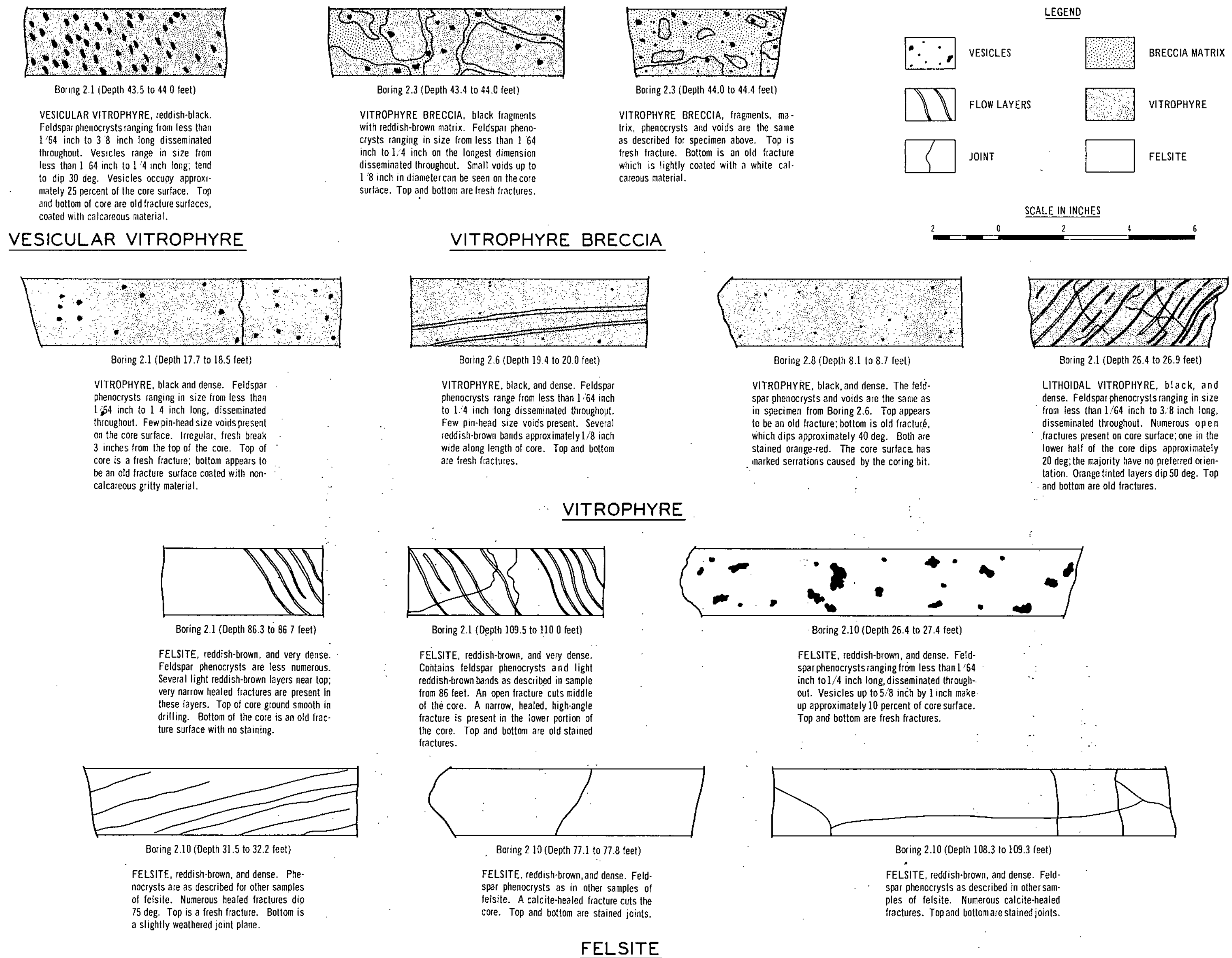


Figure C.1 Description of NX core samples.

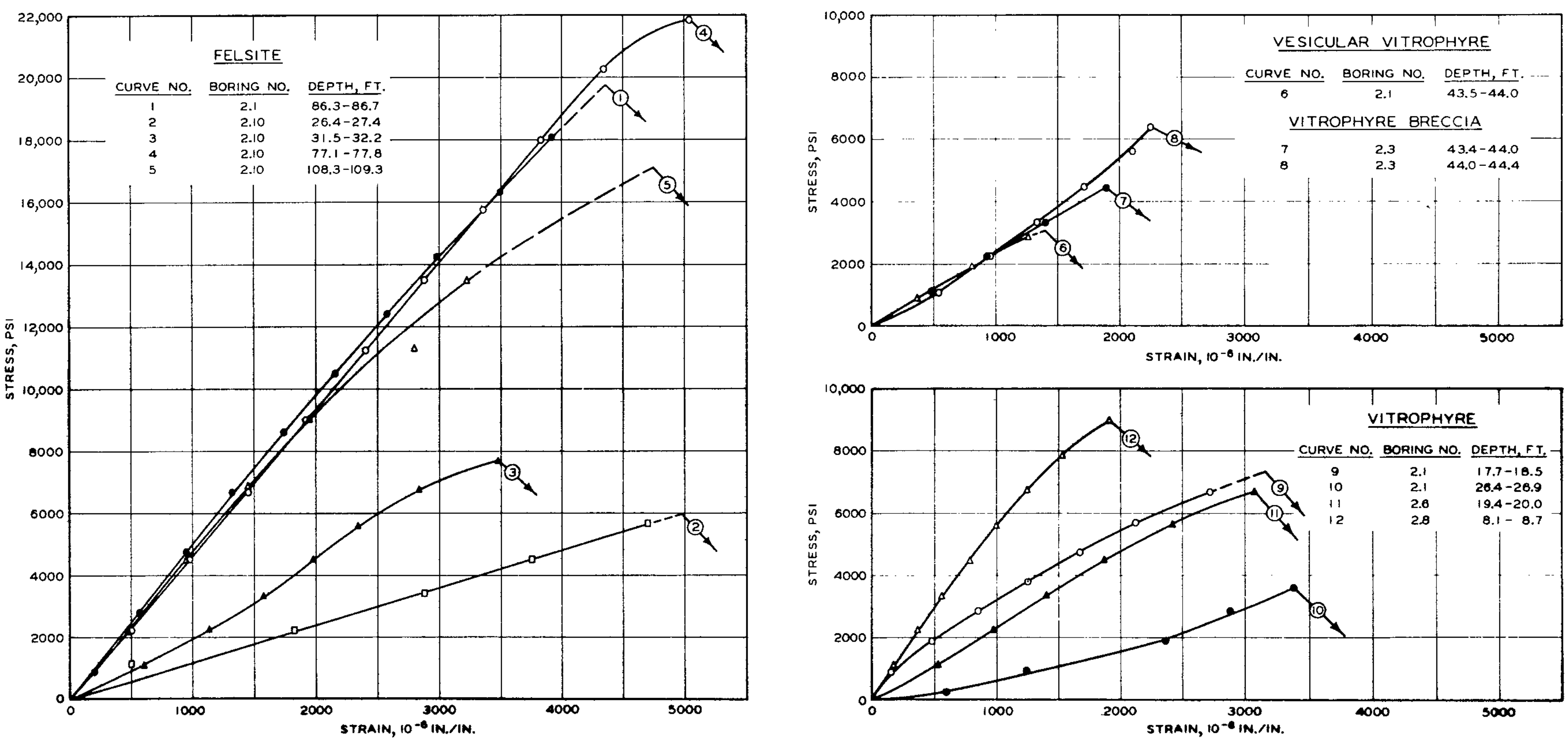


Figure C.2 Stress-strain curves from unconfined compression tests.

APPENDIX D

PETROGRAPHIC EXAMINATION OF ROCK CORES
FROM BORINGS 2.1 AND 2.3

APPENDIX D

PETROGRAPHIC EXAMINATION OF ROCK CORES FROM BORINGS 2.1 AND 2.3

D.1 SAMPLES

Samples of four NX-diameter rock cores from Borings 2.1 and 2.3 at the project site were received for petrographic analysis. The samples consisted of short end pieces of core, the tops and bottoms of core lengths from which cylinders for physical tests had been sawed.

D.2 TEST PROCEDURE

The samples were examined with a stereoscopic microscope on cored, freshly broken, and sawed surfaces. The compositions of the feldspar phenocrysts and the glassy groundmass of each sample were determined from grain immersion mounts with a petrographic microscope. Representative samples of each rock and of hand-picked phenocrysts from each rock were prepared and examined on an X-ray diffractometer. A thin section of Sample 4 was made and examined with a petrographic microscope. Photomicrographs of a selected area within the thin section and of the sawed surface of the rock were made to illustrate pertinent features.

D.3 RESULTS

D.3.1 Sample 1 (Boring 2.1, Depth 17.7 to 18.5 Feet). The

sample was a brownish-black (5YR 2/1), glassy, porphyritic igneous rock consisting of white, clear, and tan subhedral to anhedral feldspar phenocrysts and scattered pyroxene phenocrysts in a dark glassy matrix. The feldspar phenocrysts ranged in size from less than 1/16 to about 3/8 inch in longest dimension, most frequently 1/16 to 1/8 inch. The rock was rather soft and could easily be scratched with a needle; it was readily fragmented with light hammer blows and even by crushing between the fingers. Much of the groundmass has a resinous luster; an iridescent play of colors could be seen on freshly broken surfaces. The glassy groundmass had a somewhat perlitic texture. Abundant perlitic cracking was noted on sawed surfaces. When the rock was fractured with a hammer or crushed between the fingers, the glass usually broke up into rounded grains. This kind of breaking is related to water content and cooling history of the lava from which the rock solidified. The rock was only very slightly vesicular. Most of the apparent vesicles observed on sawed surfaces were due to small, rounded glass grains plucked out by the sawing action.

The sample constituting the top piece of the core length was about 3-1/2 inches long, massive, and virtually unweathered. The bottom piece was about 2 inches long and was fractured on one surface at about 30 degrees to the axis of the core. That part of the rock bordering the fracture and extending back into the rock from

1/4 to 1/2 inch was highly weathered and leached to a soft, yellowish-white material. X-ray diffraction analysis of this material indicated that it was composed of a mixture of amorphous glass, residual feldspar from phenocrysts, and a poorly crystalline clay mineral that was probably halloysite.

X-ray diffraction analysis of the unweathered rock indicated that it was composed of glass, plagioclase feldspar, very minor amounts of pyroxene, and a trace of quartz. Index-of-refraction measurements and other optical properties obtained from grain immersion mounts of the feldspar phenocrysts indicated that the feldspar was oligoclase. Grain mounts of the glass indicated that, although it was essentially amorphous, it was almost opaque because of the presence of myriads of extremely small bubbles, microlites of iron oxide, and needlelike crystallites embedded in it, which were visible only at 450X. The index of refraction of the glass was near 1.500. The silica content of the glass, based on the index of refraction, was about 72 percent. When a small, coarsely ground sample of the rock was subjected to magnetic separation with an electromagnet, virtually all the glass particles were picked up, leaving only the fragments of feldspar phenocrysts and a few small, almost spherical quartz grains in the nonmagnetic fraction. The roundness of the quartz grains indicated that the quartz had been an early product of crystallization, rounded by corrosion by the

magma to the extent that all crystal outlines had been lost.

The composition and texture of the glassy groundmass of the rock, together with the acid plagioclase phenocrysts--oligoclase--suggest that the magma from which the rock solidified was of rhyolitic composition. Based on composition and texture, the rock was classified as a porphyritic rhyolite vitrophyre.

D.3.2 Sample 2 (Boring 2.1, Depth 26.4 to 26.9 Feet). The sample consisted of two pieces of core, each about 1-1/2 inches long and bounded by a fracture plane running diagonally along one side at about a 50-degree angle to the axis of the core. The rock was brownish-black, glassy, porphyritic igneous rock with discontinuous paper-thin to 1/16-inch-thick layers of dense, reddish-brown glass dipping at about 45 to 60 degrees to the axis of the core. The layering was approximately normal to the fractured surfaces. The phenocrysts consisted of euhedral to subhedral feldspar and a few corroded quartz and ferroan mineral crystals of similar size and distribution to those in Sample 1. The groundmass of the top pieces of core exhibited two types of texture, partly the perlitic type, as in Sample 1, and partly a more dense, nonvesicular, layered texture composed of somewhat devitrified glass. The bottom piece of core was the dense, layered type. The rock was highly fractured with short, irregular, intersecting cracks that rendered the small pieces of core very weak. They could easily be broken into small fragments

by crushing between the fingers. The rock was relatively unweathered, although the two principal fracture surfaces were partially coated with dusty white powder.

X-ray diffraction analysis indicated that the rock was composed of plagioclase feldspar, poorly crystalline, disordered cristobalite-tridymite, resulting from devitrification of the glass, traces of quartz, and possibly very minor amounts of pyroxene. Grain immersion mounts indicated that the feldspar phenocrysts were oligoclase. The glass in the two textural varieties was distinguishable in grain mounts. The perlitic glass, like the glass in Sample 1, was almost entirely amorphous, contained crystallites and bubbles, and had an index of refraction near 1.50. The more dense glass, on the other hand, possessed a very dull salt-and-pepper birefringence, appeared to contain fewer bubbles, and had a mean index of refraction near 1.51. The presence of disordered cristobalite-tridymite, demonstrated by X-ray diffraction, was suggested by the wedge-shaped extinction units in the glassy matrix. The X-ray diffraction interpretation is believed correct, since both cristobalite and tridymite and disordered mixtures of the two are common products of devitrification of siliceous volcanic glasses. Evidences of partially crystalline order could be detected by X-ray diffraction before the same sample was shown to be crystalline by the light microscope.

Although there were slight differences in composition and

texture between this rock and Sample 1, the similarities of the two rocks were such that this rock was also classified as a porphyritic rhyolite vitrophyre.

D.3.3 Sample 3 (Boring 2.1, Depth 109.5 to 110.0 Feet). The sample consisted of two pieces of rock core with a total length of 2-1/4 inches. Both pieces were described as having come from the top of the core length. The rock was a dense, porphyritic, light brownish-gray (5YR 6/1), purplish-tinged igneous rock. The phenocrysts were of similar size and composition as in the other two samples. The rock contained a few paper-thin, discontinuous, recemented cracks running about 15 to 25 degrees to the axis of the core. No signs of physical weathering other than a slight discoloration of the top fracture surface were noted.

X-ray diffraction analysis of the ground rock indicated that it was composed of plagioclase feldspar, disordered cristobalite-tridymite, traces of quartz, possible pyroxene, and possible alkali feldspars. The plagioclase in the phenocrysts was oligoclase. The lines produced by tridymite-cristobalite were sharper than the corresponding lines in patterns of Sample 2, indicating better crystallinity achieved by more complete devitrification of the glass. The glass was more birefringent than in either of the other two samples, having a salt-and-pepper appearance not unlike that of chert when viewed through crossed nicols; the mean index of refraction of the

glass was about 1.504. Even at extremely high magnification the optical properties of the birefringent material in the glass could not be determined with any degree of accuracy. An X-ray pattern of the glassy material that had been hand-picked to exclude as many of the phenocrysts as possible indicated that the glass probably contained some alkali feldspar in addition to the tridymite-cristobalite. This feldspar was probably present in the glass as cryptocrystalline felsitic aggregates of feldspar and tridymite-cristobalite.

Iron oxide microlites were present throughout the glass. After grinding, virtually all the glass was attracted by an electromagnet.

The rock was also classified as porphyritic rhyolite vitrophyre on the basis of its mineral composition and texture.

D.3.4 Sample 4 (Boring 2.3, Depth 43.4 to 44.0 Feet). The sample consisted of two pieces of core. One piece was about 2-1/2 inches long, one end being a saw cut and the other a fracture plane approximately normal to the axis of the core. A small piece had been broken off the core along a high-angle fracture plane (at about 80 degrees to the other fracture). The other piece was about 1-1/2 inches long, with one end formed by a saw cut and the other by a fresh, rough fracture at about 30 to 45 degrees to the axis of the core. The rock was unweathered.

The core consisted of a somewhat marbled, reddish-brown and brownish-black, glassy, porphyritic rock made up of highly brecciated

brownish-black porphyritic and slightly perlitic-textured volcanic glass that had been thoroughly intruded by reddish-brown slightly vesicular glass. The vesicles were concentrated in very thin veinlets of the red glass, which had intruded between the brecciated black glass particles. The vesicles were usually elongated, and were probably formed as the result of cracks between the brecciated particles being incompletely filled with the molten lava before it solidified to form the red glass. The black glass itself was similar in composition and texture to that of Sample 1.

Phenocrysts in the rock consisted of white to tan euhedral to subhedral plagioclase feldspar crystals measuring from about 1/16 to 1/8 inches in longest dimension, a few clear to yellowish-green pyroxene phenocrysts, and a few corroded quartz crystals of similar size. The glass had a vitreous luster on freshly broken surfaces.

The rock was only moderately hard, could easily be scratched with a steel dissecting needle, was readily crushed with light hammer blows, and small pieces could be crushed between the fingers. Crushed fragments entirely composed of or containing black glass were attracted by an electromagnet, whereas fragments of red glass only were nonmagnetic.

Grain immersion mounts of the black glass indicated that it was amorphous to the light microscope; however, the presence of many extremely small microlites of opaque iron oxide, and of needle and

lath-shaped crystallites rendered the particles almost opaque to transmitted light. The index of refraction of the glass was near 1.500 (1.498-1.502). Grain mounts of the red glass, on the other hand, showed that it varied from amber in small grains to deep reddish-brown in larger, thicker grains. These grains also contained tiny crystallites, most of which were lath- or rod-shaped; however, very few iron-oxide microlites were seen. The red color of the glass was undoubtedly due to the presence of ferric iron in solid solution in the glass. The index of refraction of this glass was slightly higher than that of the black glass: 1.506 versus 1.500. Both glasses had silica contents in excess of 70 percent, based on index of refraction. The composition of the plagioclase phenocrysts, as determined from index of refraction and other optical properties and from X-ray diffraction, was oligoclase.

In thin section the black glass appeared as light-gray to brownish-gray amorphous glass in which flow structure was evidenced by slight color banding. The bands were composed of darker and lighter gray glass containing many extremely small microlites oriented essentially parallel to the banding. Perlitic texture in the glass was exhibited by the presence of rounded perlitic cracks. In some cases the glass in the center of the perlitic crack rings had been plucked out during the preparation of the thin section. Cracks between the brownish-gray particles were filled with the

intrusive red glass. The contact between the brownish-gray glass and the red glass was usually characterized by a thin yellowish zone next to the brown glass followed by a thin, deep red zone that graded into a lighter, reddish-yellow, locally vesicular glass that constituted the major part of the crack filling. In some instances the yellowish zone next to the brown glass was not present. The zoning might possibly be due to partial melting of the surfaces of the brecciated brown glass particles by the molten red glass. Figure D.1 illustrates the zoning described above. Phenocrysts observed in the thin section consisted mainly of plagioclase feldspar in varying stages of alteration and corrosion, a few quartz crystals with corroded edges, and fairly abundant pyroxene phenocrysts, many of which were altered in part to iron oxide. An occasional spherulitic particle, probably cristobalite, was noted in the red glass. Figures D.1 and D.2 show the texture of the rock and illustrate the amorphous character of the glass.

X-ray diffraction analysis of the rock indicated that it was composed primarily of glass with minor amounts of plagioclase feldspar, very minor amounts of quartz and pyroxene, and possibly small amounts of poorly crystalline cristobalite. X-ray patterns of both the brownish-black and the red portions of the rock were characterized by broad halos due to amorphous glass.

D.4 SUMMARY

Petrographic examination and X-ray diffraction analysis of four core samples indicated that all had similar mineralogical composition, being composed primarily of megascopic plagioclase feldspar phenocrysts (oligoclase) and a few small corroded quartz and ferroan mineral phenocrysts in rhyolitic glass groundmass.

Three of these samples were classified as porphyritic rhyolite vitrophyre. The glass in Sample 1 was essentially amorphous, but the glass in Samples 2 and 3 was progressively more devitrified. The products of devitrification in the latter two samples were disordered cristobalite-tridymite, and perhaps cristobalite-tridymite-alkali feldspar intergrowths in the case of Sample 3. None of the samples were physically weathered to a significant degree, although some leaching was observed along a fracture plane in Sample 1. The glass in Sample 1 was softer than that in the other two samples owing to its perlitic structure. Sample 2, although hard and dense, was physically weak due to internal fracturing. Sample 3 was both hard and dense and contained no open fractures.

Petrographic examination of Sample 4 indicated that it was an unweathered porphyritic rhyolite vitrophyre that had been thoroughly brecciated and later recemented by intrusion of reddish-brown rhyolite glass. Except for the fact that the rock had been

brecciated and later intruded, Sample 4 was very similar in composition and texture to Sample 1, and the two types should exhibit similar physical properties.

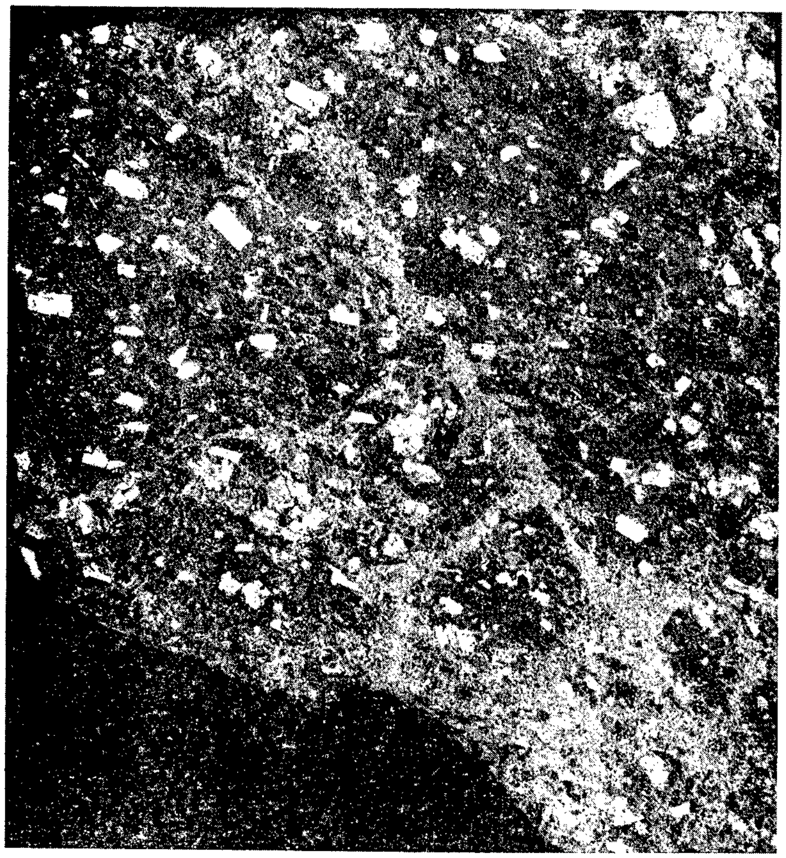


Figure D.1 Sample 4, sawed surface of core cut parallel to axis of core. The light-colored portions of the groundmass of the rock are composed of reddish-brown glass that surrounds the darker glass fragments.

A. Photomicrograph in plane light.

B. Photomicrograph in cross-polarized light.

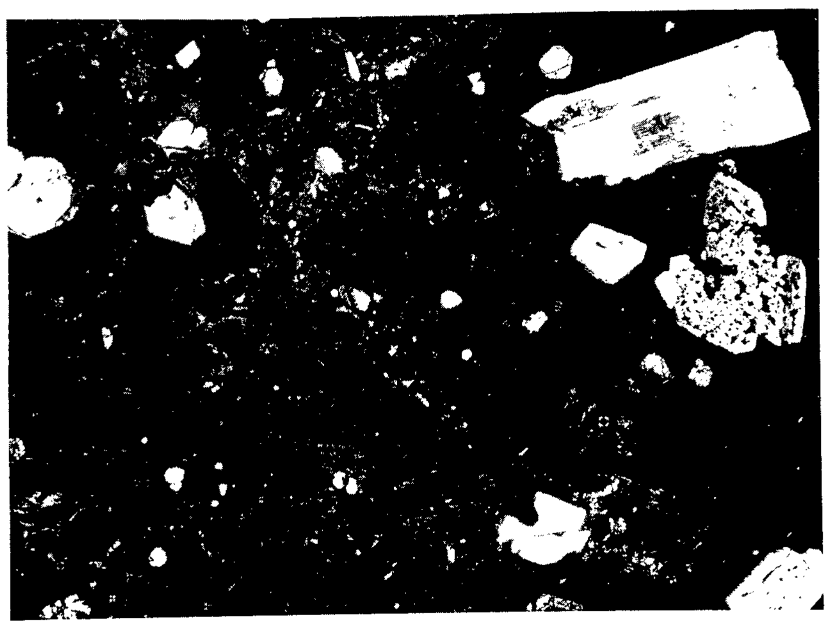


Figure D.2 Sample 4 in thin section. Photomicrograph A in plane light illustrates the textural features. Complex banding occurs in the red glass just inside its contact with the brecciated brownish-black glass. Irregular white areas are cavities. Euhedral feldspar phenocrysts are scattered throughout. Two fractured quartz crystals rounded by corrosion are seen at upper left. Photomicrograph B is the same field under cross-polarized light. The amorphous character of both the red and the dark-brown glass is verified by the almost complete extinction of the groundmass.

APPENDIX E

REGIONAL GEOLOGY

APPENDIX E

REGIONAL GEOLOGY

The rocks of south-central Idaho can be divided into moderately deformed volcanics and continental sediments of Cenozoic age and the underlying, highly deformed, sedimentary and intrusive rocks of Mesozoic and Paleozoic age.

E.1 PHYSIOGRAPHY

The ground surface in the Bruneau drainage basin slopes northward from the Jarbidge Mountains (elevation 10,000 feet) for 70 miles to the Snake River (elevation 2,500 feet), with the first 10 miles on the south being steep and rugged. A sizable part of this surface is on basalt, and in spite of subsequent faulting, erosion, and soil development, the surface exhibits some of the gross features of volcanic terrain, particularly shield cones and lava flows.

At four of the five areas examined and at the proposed Schooner site, older, silicic volcanics constitute the bedrock. Resistant hills of felsite with over 100 feet of relief characterize the rounded terrain. Again, the topography appears to result first from primary rock structure and second from erosional processes (see Chapter 3).

The widely spaced, intermittent streams that originate within

the area have essentially a poorly developed dendritic pattern. Small, shallow playas scattered over the plateau surface adjacent to the West Fork Bruneau River have interrupted the development of normal surface drainage. In contrast to the local intermittent streams, the few widely spaced perennial streams originating to the south have eroded narrow, steep-sided canyons, e.g. the canyon of West Fork Bruneau River is about 900 feet deep and less than 1 mile wide near the site.

E.2 STRATIGRAPHY

Pliocene-Recent rocks in the adjacent Snake River Valley are grouped from youngest to oldest into: (1) the Snake River group (basalts and interbedded gravels), (2) the Idaho group (gravels, finer grained sediments, and basalt), and (3) Idavada volcanics (silicic welded tuff and subordinate, unwelded vitric tuff and lava flows). South of the Snake River, these formations rise and end in cliffs exposing the lower, more deformed Tertiary volcanics.

<u>E.2.1 Snake River Group</u>. The Snake River group, upper Pleistocene in age, consists of interbedded basalt and gravel largely confined to the center of the Snake River structural depression. Component formations have been studied in the Snake River Canyon near Hagerman where 8 units (Reference 4) with a total thickness of 550 feet are exposed.

<u>E.2.2 Idaho Group.</u> The Idaho group, middle Pliocene in age,

has been described in Reference 4 in typical exposures along the Snake River. Drilling near Glenns Ferry indicated a thickness of 3,000 feet, but because this section has probably been deposited in a subsiding basin roughly outlined by the present Snake River Valley, the group can be expected to thin southward.

Formations consist of clastic beds and intercalated basalt flows. The clastics generally range from sand to clay, but they include some gravel, volcanic ash, and diatomite. Although the beds are consolidated, they are generally not lithified, and massive beds several hundred feet thick commonly erode to badlands topography. Seven formations in the Snake River Valley are distinguished in Reference 4.

Basalt flows occur in two formations. The lower of these formations, the Banbury basalt, crops out at or near the surface on much of the plateau that includes the five areas of principal interest in this report. However, at four of the areas, the Banbury and younger basalts are missing.

The Banbury basalt, in the type section on the Snake River, is divisible into three parts. The lowest part consists of at least 400 feet of greatly decomposed olivine basalt that usually occurs as amygdaloidal flows about 15 feet thick, although some columnar flows are about 30 feet thick. The middle part, about 100 feet thick, consists mainly of brownish sand and pebble gravel

in lenticular stream deposits, but includes some light-colored clay, silt, and diatomite in lake deposits as well as beds of siliceous volcanic ash. The upper part of the Banbury basalt, in places 500 feet thick, is composed mainly of olivine basalt in columnar lava flows as much as 50 feet thick. Thin, lenticular beds of sand and silt locally separate flows. The upper part, although considerably weathered, is less decomposed than the lower part.

E.2.3 Idavada Volcanics. Somewhat more disturbed silicic volcanics of lower Pliocene age underlie the Idaho group in much of the region and form the dominant bedrock in four of the five areas discussed in this report. These volcanics are named the Idavada volcanics (Reference 4) and occur both north and south of the Snake River Valley. Chemical analyses (Reference 6) suggest that they are rhyolites or quartz latites.

E.2.4 Older Tertiary Formations. Below the Idavada volcanics, rhyolitic rocks of middle or early Tertiary age may be expected.

Based on the stratigraphic sequence in the Jarbidge Mountains (Reference 7), these earlier Tertiary rocks probably consist of numerous flows including units regarded as ignimbrites or welded tuffs. Individual flows may range from thirty to several hundred feet in thickness. Although flows dip only gently, they tend to rise toward higher elevations as though the Jarbidge Mountains occupy a structural dome.

E.2.5 Mesozoic and Paleozoic Formations. Pre-Tertiary rocks can be considered together as the basement because they are distinct in structure and lithology from Cenozoic formations. The nearest exposure of pre-Tertiary rocks is near Jarbidge, over 30 miles to the south. A single piece of dense limestone found loose on a felsite knob, 2,000 feet southwest of the Pre-Schooner II site, is interpreted to be a xenolith of wall rock plucked at depth from the conduit of the vent from which the lava issued. Other rocks that can be expected to underlie the Cenozoic deposits are quartzites, feldspathic sandstones, metavolcanics, and granitoid intrusives.

E.3 STRUCTURAL GEOLOGY

Regional deformation becomes more conspicuous with age of the formations. With due consideration for initial (depositional) dips, an increase in tectonically induced dips can be expected from less than 1 degree in the Snake River Valley to 15 degrees or more in the older rhyolite complexes to north and south. Most of the dips in the Bruneau River basin (Figure 1.1) are toward the north, and the formations above the Miocene units are parts of a gentle homocline. Formations are known to steepen, locally, in monoclinal flexures adjacent to the Snake River Valley in disappearing beneath younger formations.

Some of the monoclinal flexing has probably taken place over faults that are believed to bound the valley. West-northwest

topographic linears shown on the Twin Falls 1:250,000 map and photograph index in the Sailor Creek aerial gunnery range are at least partly a consequence of faulting such as has been found on Bruneau River near Hot Spring (Reference 8) and as shown in Reference 9. A west-northwest trend is also prominent to the west among faults at Silver City and DeLamar south of the edge of the valley. Surprisingly little of the west-northwest trend is evident as faults or joints in the area surrounding the test site.

A second set of linears consisting of fault and/or dike traces arranged en echelon trends north-northwest across the area parallel to the East Fork Bruneau River. This trend, which encompasses the principal strikes in veins of the Jarbidge district, possibly governed the locus of extrusive centers there (see Reference 7). These linears may have controlled the localization of the group of shield volcanoes aligned north-northwest 6 miles east of the Pre-Schooner II site. A third, conspicuous, localized zone of linears trends south 70 degrees west from Sailor Creek, about 25 miles east-northeast of the Pre-Schooner II site, to Clover Flat Ranch about 11 miles east of the site. The zone is thus 14 miles long and 2 to 3 miles wide. Less distinct extensions of the structures continue across the basalt terrain just east of the test site on strikes of about east-west. Presumably, a few of these east-west structures reach the immediate vicinity of the test site, though none

were recognized there in field work.

The increasing degree of deformation with increasing age of the formations is a consequence of the accumulation of effects of each period of orogenic activity. Formations of Paleozoic age, having experienced orogenies in the Paleozoic and Middle Mesozoic and during all subsequent periods of deformation, are generally folded and faulted extensively and locally intruded by igneous rocks.

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13. ABSTRACT

The Pre-Schooner II site was selected, from five areas investigated, on the basis of refraction seismic surveying, core drilling, and surface mapping in extrusive igneous rock that generally models the nearby Schooner site. Bedrock below about 5 feet of stony silt consists of a 25-foot-thick layer of vitrophyre and vitrophyre breccia over felsite that extends to a depth of at least 150 feet. These two bedrock layers at the site have distinctly different physical properties, the felsite being relatively less porous and stronger in compression than the overlying vitrophyre. The felsite is massive at depth, although highly fractured, but it becomes steeply flow-layered in the upper portion. The flow layers continue across a gradational zone into the overlying vitrophyre. The resultant structure strikes about north 35 degrees east. The felsite is conspicuously jointed, and the vitrophyre contains abundant microscopic cracks.

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